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*Publication date:*
2000

*Document Version*
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

*Citation (APA):*
Nielsen, L., & Olsen, K. R. (2000). *Joint implementation, clean development mechanism and tradable permits. International regulation of greenhouse gases. Appendix*. Risø National Laboratory. Denmark. Forskningscenter Risoe. Risoe-R No. 1197(App.)(EN)

Risø-R-1197(EN)

# Joint Implementation, Clean Development Mechanism and Tradable Permits

## International Regulation of Greenhouse Gases

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# Appendix

Risø National Laboratory, Roskilde
June 2000

# DISCLAIMER

# Appendix

*Working Papers, Conference Papers, etc., which form part of the background analysis for the main report.*

Joint Implementation and Accreditation of Emission Reductions. Working Paper.

Comparing Joint Implementation with Tradable Permits – what are the pros and cons? Paper presented at the IAEE conference in Berlin, 1998.

Joint Implementation as an option for developing countries to improve bargaining power – Two bargaining games for a global regime of emission trading in the Climate Convention. Paper presented at the 22nd IAEE Conference Rome June 1999.

Developing Countries in the Climate Convention, The Greenhouse Paradox. Working Paper.

Will CDM be an Obstacle to Later Commitment by Non Annex B Countries to Fixed Reduction Targets. Working Paper

Quota prices.
Paper partly financed by the EFP (1998) funded project 'CO2 permits in Danish and European energy policy'.

WORKING PAPER

# Joint Implementation and Accreditation of Emission Reductions

*Abstract: A "correct" accreditation is a key issue when evaluating Joint Implementation as a global environmental instrument. Problems mentioned in the literature on Joint Implementation — including the problem of additionality — are often relating to the problem of defining a correct accreditation. This paper lists some of these problems and lists some of the tools available to solve the reported problems of accreditation. The paper concludes that the institutional framework is crucial in defining what a correct accreditation is. It also concludes that different groups may have different interests in Joint Implementation, and that each of the reported problems may be a problem to some of the Joint Implementation interests groups but not to others. In designing the institutional framework for JI it is important to know the incentives and motivations of the different groups. The main part of the paper is an analysis of the basic incentives and motivations of the different Joint Implementation interest groups. This analysis can be used to weight the problems of Joint Implementation from an environmental perspective and from the perspective of cost effectiveness.*

## 1. Introduction

This paper deals with accreditation. Im- or explicitly this is what the bulk of literature on Joint Implementation is dealing with. The accreditation aspect is what characterises Joint Implementation from other instruments, and the problems relating to accreditation are the problems to be solved to make Joint Implementation operational. Issues like baseline, additionality, incremental costs, control, cost curves, fairness and equity — discussed in extension in the literature on Joint Implementation — are all related to the accreditation methodology. The following will describe how.

Joint Implementation is an environmental economic instrument, which involves both market forces and administrative procedures:

The aim of Joint Implementation is to level out differences in cost of emission reductions between countries, regions or for example firms. Host countries supply emission reduction projects, and donor countries demand emission reduction projects at costs, which are as low as possible. If prices are right, the donor countries finance the emission reduction projects in the host countries. Prices equalise supply and demand, and Joint Implementation in this way makes use of the market forces.

The reason why donor countries are interested in financing emission reductions in other countries is that Joint Implementation allow the donor countries to substitute between emission reductions at home and abroad, and allow them to be accredited the emission reductions financed abroad. The accreditation of emission reductions abroad is crucial to the donor countries because the higher the accredited emission reduction, the easier and the less expensive it will be to fulfil the national emission reduction targets. The accreditation procedure is an administrative procedure involving official acceptance of (in principle) every single JI project.

The market for JI projects levels out differences in emission reductions costs between countries, delivers a price on emissions reductions (for example a price per ton $CO_2$ reduced) and minimises in-optimalities. The market price is conditional on the institutional framework for JI. What the market can not do by itself is first, to assure that there is a *limit* to the *supply* of projects to the market for JI, and second, to avoid *cheating* and *leakage* effects. The institutional framework must deal with these problems.

The main problems connected to an international acceptance of JI as instrument are tied to the problems of avoiding extensive cheat and extensive leakage effects and the problems of additionality (limiting the supply of JI projects): For the instrument to be effective, it is important that national and international acceptance of JI projects are limited to projects which contribute to reduce global emissions *by more than would otherwise have been done,* and it is important that the national and/or international accreditations of these projects reflect real emissions reductions. If it is possible to bring cheating and leakage effects to a minimum, and possible to assure that credit is assigned only to the "right" projects — JI will be a desirable instrument in theory and in practice.

The theoretical and practical problems connected to JI are mirrored in the accreditations, and therefore it may be informative to compare the problems in relation to their effects on the accreditation.

The accreditation of emission reductions raises a long range of practical and theoretical problems. These problems are dealt with in the following section 2. Section 3 deals with the "tools" needed — or available — to help a correct accreditation, and section 4-8 analyse the incentives and motivations of the different agents participating in a JI arrangement.

Section 2 concludes that a theoretically correct accreditation is non-existing. Instead the JI framework and the specific contracts associated with every particular JI project will define, what is the correct accreditation. The JI framework and the specifications in the JI contracts must cope with the problems connected to the accreditation.

The analysis of motivations, incentives and leakage in this paper demonstrate that the character of cheating and leakage is very much dependent on the host country's status as annex 1 or non annex 1 country. This point is not new, but the argument is one output from a more systematic and detailed analysis.

Internationally there have not yet been any agreements on the institutional framework needed to regulate Joint Implementation. A very important — if not the most important — criteria for which framework to choose is the ability of the institutional framework to assure that the agents incentives work in the direction of maximising the environmental and other benefits of JI, and minimising the associated direct and indirect costs. Sections 4-8 analyses the incentives, motivations and interests of the participants directly and indirectly involved in a given JI arrangement.

Which international framework (international rules, international bodies) there might be set up to regulate Joint Implementation in a FCCC perspective will not be discussed in this paper. And it will not be discussed which national regulations or mechanisms in the donor countries will make it advantageous to the firms or industries in the donor countries, to engage in JI arrangements.

Most of the analyses presuppose fixed reduction targets measured relative to a given base year put on all annex 1 countries.

# 2. Problems related to accreditation

There are several reasons why accreditation is not straightforward. The problems show up when you ask questions like, how to assure correct accreditations for JI projects. Problems occur on a theoretical and a practical level.

The theoretical and practical problems may best be illustrated by the fact that it is a problem even to define what a correct accreditation is:

A clear-cut definition of the theoretical correct accreditation (on the project level) is impossible, if the emission reductions associated with different JI projects (and other investments) are not separable. Non separability means that there are no theoretical answers to, how to allocate emissions reductions between interdependent JI projects.

Another theoretical and practical problem is, that it is not obvious, what will be the correct accreditation, if a JI project fails due to circumstances that the donor (and maybe even the host) have no influence on, and could not foresee. Who will bear the risk of project failures?

A large amount of the future investments in donor and host countries may imply reduced emissions. But not all these investments will be approved as JI projects — and therefore credit will not be given for every emission reduction observed in the future. Projects suitable for JI are usually limited to *additional* projects, i.e. projects that would not have been carried out without JI. Countries are supposed to make projections of the economy — reference scenarios or "baselines" — showing the development of the economy and the future emissions without JI (i.e. without the additional projects). But if JI becomes a possibility, JI may change the investment behaviour, and additionally may be a very difficult criterion. After some years with JI, JI — like every other actual policy — is taken into account in plans and projections — and the reference scenario may be constructed as a residual. The residual will show a "realistic" projection of the economy, but subtracted the projects that the countries want to be approved as JI projects. In this case additionally has no positive meaning.

Below is listed some important problems related to a correct accreditation at the project level:

- Additionality. If accreditation is given for emission reductions additional to those that would otherwise have been carried out. How can additionality be defined?
- References. The additionality concept involves a reference scenario. Should "no regret options" be included in the reference scenario (if yes, this implies that "no regret options" can not be JI projects)? Should the reference scenario include standard assumptions. Should there be special requirements to the level of energy prices in the reference scenarios — or the level of growth of energy prices?
- Time perspective. For how long time should it be possible to the donors to be accredited a specific JI project. The JI project may for example be a simple forwarding of a later baseline project.
- Project failure. Who will bear the risk of project failures. Failures may be caused by circumstances outside the control of the donor and host.
- Other (minor) uncertainties. Who will bear the risk of uncertainties. What will for example be the correct accreditation, if the emission reductions are higher or lower than projected due to higher or lower activity level — at the national economy level, or at the plant level — than projected.
- Leakage. If a JI project implies increased emissions elsewhere — for example because firms and countries change behaviours towards importing polluting goods rather than producing these goods — the net effect on emissions reductions of that project may be limited, and even negative.
- Systems effects. What will be the correct accreditation if the indirect emission reduction decreases because of for example other JI projects.

- Incentives. Who (at the project, systems and macro level) will be in a position, where they have all relevant information, so they in principle can report the emission reductions? What are the incentives to reveal the true direct and indirect emission reduction?
- Control. What are the needs for control (given different institutional frameworks)? Will the control be effective?

As it is difficult to make a clear-cut definition of the theoretical correct accreditation, and as the practical problems relating to accreditation are even bigger, the institutional framework for Joint Implementation becomes very important in defining what should be accredited for. A very simple example of the importance of institutions may be that every single JI contract specify, who will bear the burden of project failure and uncertainties, and the price of the accreditation associated with the JI project reflect the specific contract conditions. Project failures and uncertainties may be problems which can be solved by for example host and donor firms themselves. But the analysis in section 8 show that if the host and donor countries are committed by the contracts, they may want to approve or even directly negotiate the contract conditions.

The best answer to the theoretical and practical problem of defining what a correct accreditation is, may be that the accreditation depends on the institutional framework for Joint Implementation. The accredited emission reductions may be the emission reductions actually experienced in relation to a concrete project (with or without systems and macroeconomic effects (for example price effects)) or emissions reductions experienced in relation to for example a pool of projects (eventually related to the total emission reductions of the host country). The institutional framework will define at which "level of aggregation" the emission reductions can be "measured". And the institutional framework or the JI contract will specify who will bear the risk of project failure, etc.

Several parties — for example donor and host countries, donor and host firms and industries, the international community (represented by different international institutions) — may be interested in a particular JI project. Their perspectives on JI (the reason why they are interested in JI) may be different. Their main concerns are in the money transfer, the accreditation, and the emission reductions. But they are not necessarily interested in accreditation at the same level of aggregation (i.e. country, industry, systems or project level). The international (JI) institutions may for example be interested in accreditation at the country level, while accreditation at project and system levels are only of secondary interest, if at all interesting. This means that the different parties will pose different demands to the accreditation methodology (and to the institutional framework for JI), for example with respect to accuracy, treatment of uncertainties, verification and control.

At which level the accreditation is carried out is decisive to which tools are needed to assure a "correct" accreditation.

A "correct" accreditation at the project level demands a detailed and carefully elaborated accreditation methodology. The need for baselines, technical and macroeconomic models, external control of the fulfilment of the JI contract, etc. may be extensive in this case.

A correct accreditation at the country level may, with respect to $CO_2$ , be fairly simple. It may be as simple as, a technical measuring of the $CO_2$ emissions at two different dates for two different countries engaging in JI arrangements with each other.

Given a demand for a correct accreditation at the project level, the institutional framework should be designed in a way so as to minimise cheat, and to minimise the necessary control of the claimed accreditations. The framework must deal with, how to reveal the, in principle, private information concerning the exact emission reductions, how to avoid incentives to cheat, how to take account of systems and other effects, project failures etc. An effective control of the project data is essential at this level of accreditation. The framework must make the effective control possible.

If successful the accreditation methodology (the JI framework) must deal with the problems listed above. Section 4-8 analyse the list from the perspective of the agents involved in JI. To whom is additionality a problem, who needs baselines etc. The analysis show that the different agents have different interests, incentives and motivations.

# 3. How can the problems related to accreditation be dealt with?

In the previous sections the expression "correct accreditation" was used in the meaning "the theoretical correct accreditation". But as mentioned this idea of a correct accreditation is not possible neither in theory nor in practice.

In practice a correct accreditation is defined according to the accreditation methodology specified by the particular framework for JI in question. As it may be useful to refer to both the "theoretical correct accreditation" and the "accreditation specified by the JI framework" the later is referred to by the term "framework accreditation".

Different "tools" may be needed or help/assure a correct framework accreditation. Some of these are listed below.

- Appropriate macroeconomic models.
- Appropriate technical models — project and/or system level.
- Official (and other) physical plans for the energy supply sector, and energy demand.
- Official forecasts of the macroeconomy.
- List of existing and planned policies with relevance for emissions.
- Official definitions of terms relevant for the accreditation, for example a definition of baselines.
- Control
- International agreements on, and accept of, the accreditation procedures

The tools may be used to construct:

- Baseline scenarios
- JI scenarios
- Cost curves for emission reductions.

— and to implement effective control.

The tools on the list are all tools that especially the *host governments* may want to use to help prioritising JI projects, and to help the *host government* prevent that individual firms or industries via JI-arrangements commit the host country to reduce emissions more than these firms and industries themselves can be hold responsible for. The tools may also be used to help control the actual emissions from the firms and industries, and to take the interrelationship of projects (for example system effects and macroeconomic effects) into account

The donor government may be interested in baselines, cost curves, plans, etc. pertaining the host countries to evaluate the market, the prices and the potentials in the host countries for emissions reductions and Joint Implementation. The donor governments — and the donor plants and industries — may have special interests with respect to the particular (type of) JI project (and the economic and technical environment to the project) that they want to engage in. A macroeconomic projection of the host economy may give the donors some idea of for example the uncertainties with respect to the emissions reductions connected to a particular project

The donor governments may want these tools — baselines and cost curves for the donor country itself — to help prioritising between the amount of emissions reductions carried out at home and abroad, and which emissions reductions projects should be carried out at home.

Host industries and plants need projections of the future markets for their products — and good estimates of their likelihood of /ability to reduce emissions

# 4. The interests of the "players" in JI

Cheating and leakage effects become problems because some of the participants in JI arrangements have other interests than the environment. This section analyses the participants (agents/players) primary and secondary interests in JI. The interests of the participants will influence their attitudes to baselines, additionality, control etc.

The analysis tell something about in which direction different agents may wish to exploit JI if they follow their own interests. Especially big donors or hosts may be in a position to exploit their market powers on the market for JI. An example could be that host firms are "forced" to use technology produced or developed in powerful donor countries.

The analysis may also tell something about conflicting or mutual interests of the different agents: donor and host, host country and host firm, etc.

The knowledge of primary and secondary interests of the agents and conflicting and mutual interests of the agents is valuable when designing the institutional framework for JI.

The table below assumes fixed reduction targets (uniform or non uniform) posed on donor and annex 1 host countries. If there were no fixed reduction targets all hosts would have the same interests and motivations as non annex 1 hosts. Donors would not have fixed reduction targets as driving force and primary interest but another incentive to engage in JI. Otherwise the interests of the donors would be the same.

It is obvious that what the table lists as the agents primary and secondary interests, will not be true in all cases. Countries and even firms may for example have the environment as first priority. What is listed is the interests and motivations when emissions reductions are analysed as a free rider problem. The area of Joint Implementation will typically be emissions with global deposition, for example $CO_2$ , and for this type of emissions free riding may be a serious problem.

*Table 1: Agents motivations to participate in JI arrangements*

| | Primary interests | Secondary interests |
|---|---|---|
| International Bodies | Environment.<br>That countries keep to their reduction commitments (to obtain the full environmental effects).<br>An environmentally and economically efficient emission reduction effort (to assure the success and credibility of the policy). | JI as development aid<br>Transfer of technology |
| Donor countries | Keep the emission reduction targets (to avoid a bad international reputation and to avoid possible sanctions)<br>To buy the emissions reduction as cheap as possible | Environment<br>To promote national technology and products in the host countries. |
| Host Countries | | |
| a) annex 1 | To sell emissions reductions as dear as possible — without hindering the fulfilment of the country's own commitment at low costs (good business).<br>New and resource saving techniques are introduced and financed by foreign countries/firms/industries | Local environmental benefits |
| b) non annex 1 | To sell emissions reductions as dear as possible. There will be no limit to the supply of JI projects.<br>New and resource saving techniques are introduced and financed by foreign countries/firms/industries | Local environmental benefits |
| Donor industries | To avoid the burden of national measures (fixed commitments, taxes, etc.) and to buy emissions reductions as cheap as possible. | To promote own products or own technology.<br>To promote a desired environmental profile |
| Host industries | To sell emissions reductions as dear as possible.<br>New and resource saving techniques are financed by foreign countries/firms/ industries (may be a competitive advantage) | Local environmental benefits |
| Donor firms | To avoid the burden of national measures (fixed commitments taxes, etc.) and to buy emissions reductions as cheap as possible. | To promote own products or own technology.<br>To promote a desired environmental profile |
| Host firms | To sell emissions reductions as dear as possible.<br>New and resource saving techniques are financed by foreign countries/firms/ industries (may be a competitive advantage). | Local environmental benefits. |

# 5. Leakage

A leakage connected to a JI project is an increase in emissions which are not taken into account in the accreditation for JI projects. Leakages occur at the JI plant, or in other parts of the national or international economy. Leakages may be very difficult to measure, because leakages may be indirect effects of the JI projects or because the leakage effects as just mentioned may occur in other parts of the national or international economy.

Examples of indirect leakage effects are increased activity levels caused by JI projects: In general JI may reduce energy consumption and energy demand and thereby lower energy prices. If lower energy prices stimulate to higher energy consumption — and this is not taken into account in the JI accreditation — this is a leakage effect. Another indirect leakage effect (relevant in many eastern European countries) may be increased private energy consumption for heating purposes — and increased welfare — followed by JI insulation projects.

Examples of direct leakage effects are JI projects which involve a cut of of polluting processes, or export of these processes, and buying of intermediate "polluted" products.

Leakages occur when JI projects are evaluated in "isolation" (for example at the plant level) (and in this perspective reduces emissions), but if evaluated at higher levels of aggregation (industry, country, world) reduces emissions by less, or even increase emissions.

Table 2 describes to whom leakages may be a problem.

Leakages are a problem to an agent, if the agent cannot pass it (further) on to somebody else. Leakages are a problem to the environment if *no* agents are responsible of neutralising the leakages. The institutional frameworks will im- or explicitly decide who will bear the burden of neutralising the effects of leakages. If the institutional framework or the JI contract does *not* specify explicitly who will be responsible of neutralising leakages there are several possibilities:

- donor firm/industry/country is responsible. For example: the contract specify that the donor should be accredited actual emission reductions at the plant level, but emissions at the plant level are not reduced as much as expected because of a rise in activity due to JI (better or cheaper products). This makes the donor bear the burden of leakage, because the donor gets less emissions reductions than he expected.
- Annex 1 host is responsible. For example: the contract specify that donor should have the contracted, fixed accreditation, despite the actual emissions reductions, or should be accredited the emissions reductions compatible with a specified activity level. In this case the host firm/industry or country is responsible for neutralising the leakage effects.
- Environment is victim. For example: polluting processes or firms are exported to non annex 1 countries, which do not have any national obligations to reduce emissions. The increases in emissions in these countries, due to the import of polluting processes and firms, will therefore not be offset by decreases in emissions elsewhere.

If donors and annex 1 host countries are committed by fixed reduction targets leakages are only a problem to the *environment* if the leakage effects occur in a non annex 1 country. In this respect leakage may be seen as a problem of coordinating the international agreements on fixed reduction targets. If those countries which today are non annex 1 counties are committed by realistic fixed reduction targets leakages will not be a problem to the environment. [1]

[1] Realistic fixed reduction targets means that these targets on the one hand must be compatible with the international environmental goals. On the other hand, if a substantial part of the cheap reduction potentials (low cost JI projects) is located in the non annex 1 countries, it is important to limit leakages and make the non-annex 1 counties interested in efficient emissions reductions projects (cf. table 1) by simply having a not too "loose" fixed target.

*Table 2: Types of leakages relevant to different agents, when countries emissions targets are fixed*

| | Annex 1 host country | Non-annex 1 host country |
|---|---|---|
| International bodies<br>(leakage is a problem) | Export of polluting industrial processes, firms or industries to non annex 1 countries<br>Import of "polluting products" from non annex 1 countries | Removal of polluting industrial processes, firms or industries to other firms or industries within the host economy or to other non annex 1 countries<br>Import of "polluting products" from other firms or industries within the economy or from other non annex 1 countries |
| National governments (leakage may be a benefit or a problem)<br>a) Donor<br><br>b) Host | Problem: if leakages in the host country diminish the amount of emissions reductions accredited to relevant JI projects<br>Benefit: It may be the cheapest way (also as part of JI projects) to reduce emissions, to export polluting industrial processes, firms or industries to other countries (annex 1 or non annex 1) and to import the "polluting products" from abroad<br>Problem: if leakages for example due to increasing activity levels diminish the amount of emissions reduced, and if this makes a gap between the emissions reductions sold — and legally committed to "deliver" — and the actual emissions reductions, extra steps will be necessary to reach the "revised" emission reduction target. | It will be no disadvantage to the host country to bear the "risk" of leakage unless the international body "makes it a risk". Leakage will therefore only be a problem to the donor if the international body makes it a risk to the donor.<br>Leakage is no problem to the host — unless others makes it a problem (for example by making it a precondition to engaging in JI arrangements with annex 1 countries). |
| Industries (Pool)<br>a) Donor<br><br>b) Host | Leakages in the host country /firm/industry is only a problem if the donor industry is (legally or otherwise (by sanction)) obliged to "neutralise" the leakages<br>Leakages is only a problem if the host industry is (legally or otherwise (by sanction)) obliged to "neutralise" the leakages | Leakages is no problem unless legally enforced<br><br>Leakages is no problem unless legally enforced |
| Plants<br>a) Donor<br><br>b) Host | Leakages in the host country /firm/industry is only a problem if the donor firm is (legally or otherwise (by sanction)) obliged to "neutralise" the leakages<br>Leakages is only a problem if the host plant is (legally or otherwise (by sanction)) obliged to "neutralise" the leakages | Leakages is no problem unless legally enforced<br><br>Leakages is no problem unless legally enforced |

If the donor or annex 1 host *country* bear the burden of leakages, they can pass it further on to plants or industries, consumers, taxpayers, etc.

# 6. Additionality

One of the problems about an international agreement on Joint Implementation is to limit the amount of projects supplied to the JI market. The limit inherent in the market for JI projects is the level of emissions reduction costs (there is no idea in supplying high cost projects which will have no chance of being financed through JI). But this is not the only limit relevant in an environmental perspective: There are huge numbers of projects which involves reduced emissions, but all these projects cannot be financed through JI and all the emission reductions cannot be assigned credit. The success of JI is dependent on choosing the right projects for JI.

The main purpose of JI is to reach the international environmental goals at as low extra costs as possible. The outcome of an efficient international market for JI is to give you as much direct and indirect emission reduction as possible per unit of cost. Emissions reductions which are secondary effects of normal investment practise are free. Therefore JI financing should not be given to this type of projects — and this type of projects should be excluded from the "optimal" JI market. The maximum emission reduction is obtained when the JI projects supplied at the market for JI are additional.

But how crucial is it that JI projects are additional. Is lack of additionality always a problem to the environment or is it the cost minimising property of JI which is lost.

There is no environmental effect, and therefore no cost reducing elements, in financing JI projects in non annex 1 countries, unless the JI projects are additional. If the donor countries are accredited emission reductions they off cause experience low costs, but if the net effect to the environment is zero, the JI projects has failed to bring you any step nearer the international environmental goals.

Whether additional or not, there will always be a cost reducing element in financing JI projects in annex 1 host countries as long as the emission reduction costs are lower in the host country than in the donor country. But if the JI projects are additional the environmental effects and the cost reducing effects of JI are maximised. As long as the annex 1 host country is committed by a fixed reduction target, and by international sanctions of JI contracts which means extra obligations to reduce emissions — additionality is not a problem to the environment, but a problem to the host, who does not get the optimal effects out of JI. In second place non additionality can be a problem to firms, industries and consumers because the host country can pass the extra costs of reducing the emissions on to these groups. So, when table 3 say that non additionality is not a problem to host firms and industries, this means that it is not a *direct* problem to them.

If the JI projects are not additional it will be much harder, and much more expensive, to the annex 1 host to reach the emissions reduction targets it has committed itself to reach. If this means that the annex 1 host country is unlikely to fulfil its obligations it will be a problem to the environment — and to the international bodies which have allowed the JI arrangements (therefore additionality may be an indirect problem to the international bodies). If the JI projects are not additional, there may be distributional effects between donor and host and between firms within the host country. It may be — and it seems very likely — that the donor country will pay a too low price for the accreditation, if the projects are not additional. The reason for that is that the extra JI financing is not needed in projects which would be carried out any way. So, in principle there is no lower limit to the price of the accreditation in these projects.

Non additionality may be a distributional problem between host firms and/or host industries because non additional JI projects enhance the differences in emissions reduction costs between firms/industries.

*Table 3: To whom is non additionality a problem?*

| | Annex 1 host country | Non annex 1 host country |
|---|---|---|
| International bodies | No | Yes |
| National governments | | |
| a) Donor | No | No |
| b) Host | Yes and no. Additionality of projects may be desirable, because additionality secures the extra emission reductions, which are needed to reach the targets. Given extra financing is needed to reach the target, additionality is a criteria which help securing that JI financing is given to emission reduction projects which need extra money to be realised. | No |
| Industries (Pool) | | |
| a) Donor | No | No |
| b) Host | No. (Non additionality may be an advantage to industries with non additional projects). | No |
| Plants | | |
| a) Donor | No | No |
| b) Host | No. (Non additionality may be an advantage to firms with non additional projects). | No |

# 7. Who needs baselines

A baseline is a projection of the economy and the technologies into the future. The baseline is a "business as usual" scenario and does *not* include additional JI projects. Therefore baselines are important in deciding which potential JI projects are additional (they are not in the baseline). But it is clear that the baselines technically must be very detailed if it should be possible to identify specific projects.

It is important to ask questions like: who precisely wants the baselines, is additionality the only motivation to make baselines, who makes the baselines, who should make the baselines? Baselines at which level of aggregation, how elaborated or detailed must the baselines be, who wants which accuracy of the baseline.

If the baselines are used to define additional projects, will it then be necessary to give these baselines international status. Will there be "official national baselines", and can these baselines be revised?

Table 3 shows who needs baselines for what reasons given fixed future emissions reductions targets. (If, according to the table, a donor country needs baselines, it means baselines pertaining the country itself. A donor country/firm/industry may often find it very informative to know the host countries baselines, as it may tell something about the technical and economical environmet that the JI projects are placed in).

Table 3 shows that baselines are very usefull tools, but only the international bodies need them to control JI in non annex 1 countries. The international bodies need the baselines to control additionality, accreditations and leakages in the non annex 1 countries.

The host governments may want to use baselines to help prioritising JI projects, and to help the host government prevent that individual firms or industries via JI-arrangements commit the host country to reduce emissions more than these firms and industries themselves can be hold responsible for. The tools may also be used to help control the actual emissions from the firms and industries, and to take the interrelationship of projects (for example system effects and macroeconomic effects) into account

The donor government may be interested in baselines, cost curves, plans, etc. pertaining the host countries to evaluate the market, the prices and the potentials in the host countries for emissions reductions and Joint Implementation. The donor governments — and the donor plants and industries — may have special interests with respect to the particular (type of) JI project (and the economic and technical environment to the project) that they want to engage in. A macroeconomic projection of the host economy may give the donors some idea of for example the uncertainties with respect to the emissions reductions connected to a particular project

The donor governments may want these tools — baselines and cost curves for the donor country itself — to help prioritising between the amount of emissions reductions carried out at home and abroad, and which emissions reductions projects should be carried out at home.

Host industries and plants need projections of the future markets for their products — and good estimates of their likelihood of /ability to reduce emissions

*Table 3: The need for baselines*

| | Annex 1 host country | Non annex 1 host country |
|---|---|---|
| International bodies | No need | Need (for control purposes etc.) |
| National governments | | |
| a) Donor | Useful tool | Useful tool |
| b) Host | Need, self interest | Obliged? (by international bodies) |
| Industries (Pool) | | |
| a) Donor | Useful tool. Partial baseline concerning own prospects | Useful tool. Partial baseline concerning own prospects |
| b) Host | Useful tool. Partial baseline concerning own prospects<br>Obliged ? (by national government) | Obliged? (by international bodies) |
| Plants | | |
| a) Donor | Useful tool. Partial baseline concerning own prospects | Useful tool. Partial baseline concerning own prospects |
| b) Host | Useful tool. Partial baseline concerning own prospects.<br>Obliged ? (by national government) | Obliged? (by international bodies) |

It is necessary to make a distinction between baselines for your own use and information and baselines for the use of others (control, planning, etc.). The two baselines may differ with respect to evaluations of economic growth conditions etc.

# 8. The need for control

Table 4 shows who needs control at wich level for what reason? The table can be used to say something about what should be controlled, and what kind of control is crucial to the JI process.

To ease the burden of control it is important to design the institutional framework so the incentives to "optimal" behavior, and the incentives to give correct informations are right, or more realistic, as good as possible. It is important to place the control on the JI agents which are relatively best informed *and,* in who's interest it is to reveal the information. The question is whether it is possible to create a JI framework so either the donor country has an incentive to invest only in additional projects in non annex 1 countries — or at least to reveal all relevant information — or the non annex 1 country has the correct incentives.

Table 4 show that host countries, industries and firms in general have no need for any control. An important exeption is the annex 1 host country, who want to control that the host plants and industries do not sell more accreditations, than they themselves can be hold responsible for. If the amount of JI accreditations sold are bigger than the amount of JI emissions reduced, and if the price of the accreditations are too low, the host country can be in trouble if the international bodies hold the country resposible for the JI contracts.

The international bodies need intensive and detailed control of the non annex 1 countries, but only need control at an aggregated level of the annex 1 countries.

Unless the donors have got JI contracts which specify fixed accreditations at fixed costs, they need to control, that they get the amount of accreditations payed for. When engaging in JI contracts with non annex 1 countries, both donor and host can have incentives to boost accreditations.

Governments in donor countries control that their plan for emissions reductions are "on track" — or if it is necessary to impose new regulations to get the emissions reductions targets.

*Table 4: The need for control*

| | Annex 1 host country | Non annex 1 host country |
|---|---|---|
| International bodies | Country level: Control of countries reduction commitments | Country, industry and plant level: The international bodies what to con-trol the aditionality of the JI project, the accreditation and leakages. |
| National governments | | |
| a) Donor | The "JI contract level": The donor countries want either domestic emissions reductions or accreditation for foreign JI contracts. The donor countries want to be sure or even to control that domestic doners do get the emission reductions they (on average) have payed for (if not it may be cheaper to reduce at home). The donor country may have specific demands to the type of contracts the donor firms or industries are allowed to engage in. If the JI contracts specify a fixed accreditation and a fixed transfer of money, the donor country has no need for control. | The "JI contract level": The donor countries want either domestic emissions reductions or accreditation for foreign JI contracts. The donor countries want to be sure or even to control that domestic doners do get the emission reductions they (on average) have payed for (if not it may be cheaper to reduce at home). The donor country may have specific demands to the type of contracts the donor firms or industries are allowed to engage in. If the JI contracts specify a fixed accreditation and a fixed transfer of money, the donor country has no need for control.The host has got no incentive to cheat the donor with respect to accreditations. |
| b) Host | The "JI contract level": The host countries want to control that JI accreditations are sold at prices which are high enough to cover the "relevant" costs. The host countries may want to restrict the amount of JI contracts, because it itself is committed to reduce emissions. | No need for control. |
| Industries (Pool) | | |
| a) Donor | The "JI contract level": If forced to by domestic policies (taxes, quotas, penalties, etc.), the donor industries want to control that they get the emissions reductions and accreditation specified in the JI contracts. | The "JI contract level": If forced to by domestic policies (taxes, quotas, penalties, etc.), the donor industries want to control that they get the emissions reductions and accreditation specified in the JI contracts. But this should not be a problem since the host has got no incentives to cheat the donor). |
| b) Host | No need for control | No need for control. |
| Plants | | |
| a) Donor | The "JI contract level": If forced to by domestic policies (taxes, quotas, penalties, etc.), the donor industries want to control that they get the emissions reductions and accreditation specified in the JI contracts. | The "JI contract level": If forced to by domestic policies (taxes, quotas, penalties, etc.), the donor industries want to control that they get the emissions reductions and accreditation specified in the JI contracts. But this should not be a problem since the host has got no incentives to cheat the donor). |
| b) Host | No need for control | No need for control. |

# 9. Conclusions

The preceding sectors tell something about the pitfalls of JI. And something about the problems that the institutional framework must solve. The main environmental problems are related to JI contracts with non annex 1 countries. Therefore a very effective political strategy would be to try to move all important non annex 1 countries into the group of annex 1 countries. If this can not be done, the institutional framework concerning JI arrangements with non annex 1 countries must be very specific. The analysis shows, that the non annex 1 host country (when considered as a free rider), does not care about the environment, additionality, leakage, baselines and control. Therefore the institutional framework for JI must be designed in a way so it either gives the non annex 1 host incentives to care about environment, additionality etc., or gives the donor incentives to care about the same, or gives international bodies power to set conditions for JI projects with non annex 1 countries and accept and reject projects.

If donors and annex 1 hosts acts rationally and if countries have got sufficient incentives to fulfil their fixed reduction targets, the needs for regulations and restrictions on the JI contracts are few. Maybe in this situation the most important contribution of the institutional framework to cost effectiveness and additional emission reductions, is to make the market for JI mare transparent.

# Comparing Joint Implementation with Tradable Permits

*– what are the pros and cons*

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## *Abstract*

*Joint Implementation and Tradable Permits are regarded as alternative instruments in the post Kyoto debate on environmental regulation of the greenhouse gases. The paper provides a platform for comparing and evaluating the two instruments. Key elements in the comparison are: the environmental and economic efficiencies of the instruments. But also the coordination of the instruments between countries, problems relating to initiating the instruments (for example the distribution of permits), the amount of monitoring and control needed, and the problems relating to selecting the right projects for Joint Implementation are dealt with.*

## Introduction

Choosing the right instruments is a hot issue in the national and international debates on environmental policy. Avoiding global warming, preserving the water resources, cleaning polluted soil etc. may be very costly in terms of GDP growth rates and may require substantial international cooperation and coordination. Therefore it is important to the national governments and the international environmental authorities to single out the environmental instruments which are the most effective with respect to environmental protection and economic costs, and which are easy to coordinate. The more efficient the environmental instrument the less the negative effects to the national economies.

The national and international authorities can choose between a hole range of environmental instruments. The instruments will differ with respect to cost effectiveness, environmental effectiveness, the administrative burden etc. Choosing a specific instrument may involve a trade off between certain desirable properties, for example cost effectiveness and environmental effectiveness.

This paper compares three instruments: Joint Implementation, Tradable Permits and environmental taxes. The main focus is on Joint Implementation and Tradable Permits. These instruments are regarded as alternative instruments in the post Kyoto debate on environmental regulation of the greenhouse gases. Both instruments are – at least in their text book versions – cost effective, and both instruments may be interpreted as mechanisms to impose exactly the environmental tax which will provide you a specific environmental goal. These properties makes it relevant to incorporate environmental taxes in the comparison.

A comparisons of instruments may never be complete. But the paper tries to sort out and categorise some important criteria. The paper also suggest a ranking of some of the criteria.

A problem related to a comparison of Joint Implementation and Tradable Permits is, that these instruments may be implemented in actual policy in different ways – and these different "setups" or ways to implement the instruments may affect the properties of the instrument – for example the environmental effectiveness. This fact makes the comparison more difficult, but does not however make the comparison superfluous: The comparison points to the forces and weaknesses of the instruments – and in some cases indicates whether there are solutions to problems.

Through out the paper it is assumed that TP and JI are used to eliminate *international* cost inefficiencies, because this is what is relevant in the post Kyoto debate. But both instruments may be used as purely national instruments as well. The evaluation of the instruments, when used in a national context, may however differ in some respects.

Joint Implementation may include countries without binding emission reduction commitments, whereas the countries participating in a system with Tradable Permits all have binding commitments. This difference may complicate a comparison of the two instruments. As the evaluation of Joint Implementation is very much dependent on whether the participating countries have binding commitments or not, it is relevant to compare TP with JI in both situations.

In the following section 2 a list of criteria for comparing Joint Implementation and Tradable Permits is set up. Section 3 describes how the instruments are initialised and section 4 describes how the cost efficiencies of the instruments are achieved. Section 5, 6 and 7 evaluate Joint Implementation and Tradable Permits with respect to cost efficiency, environmental efficiency and administrative burdens and section 8 concludes the paper.

## Comparing the instruments

Joint Implementation and Tradable Permits are in some respects very similar instruments. Both instruments presuppose the coexistence of other cost ineffective instruments (in a green house gas context, fixed reduction targets), and the aim of both instruments are to eliminate these cost inefficiencies induced by the other instruments. The cost inefficiencies are eliminated by setting up markets, where the agents have mutual benefit in trading the cost inefficiencies away.

The main characterising differences between the two instruments are that Joint Implementation is related to concrete emissions reduction projects and, what is traded are emissions reductions. The agents (directly) involved in Joint Implementation are those involved in concrete reduction projects. Tradable Permits are permits to pollute, and these permits must be distributed to – in principle – every single polluter, as Tradable Permits are related to – in principle – every single emission of e.g. greenhouse gasses in the involved countries. Thus the amount of trades on the markets for tradable permits and the amount of players involved in these trades may be substantial higher than is the case for Joint Implementation.

Whereas the market for TP is a market setting a price on the externalities, the market for JI is a kind of investors market: the agents invest in projects which will give - or are supposed to give – the investor a later pay off in terms of emissions reductions. The differences with respect to what is traded in a TP and JI regime give rise to significant differences in the institutional setup between the two regimes. And give rise to the different properties of the two instruments.

Comparisons and evaluations of the instruments may be done at a theoretical, a practical and a political level, where the theoretical level describes the ideal conditions under which the instrument can work, and the practical level includes the practical problems connected to the functioning of the instruments. The paper summarises some of the main differences at each level. Key elements in the comparison are: the environmental and economic efficiencies of the instruments. But also problems relating to initiating the instruments (including the distribution of permits), the amount of monitoring and control needed, and the problems relating to selecting the right projects for Joint Implementation (including the problems of creating baselines) are looked upon.

The criteria are summarised in table 1, which also indicates different rankings.

**Table 1: Criteria for evaluating the instruments, and possible rankings of the criteria**

| Criteria | Ranking from the perspective of a legislator | Ranking from the perspective of an individual agent |
|---|---|---|
| Environmental effectiveness | 1 | 6 – if agents costs are not tied to the environmental effectiveness<br>3 – if agents costs are tied to the environmental effectiveness |
| Cost effectiveness | 3 | 2 |
| Initiating the instrument | 2 | 1 |
| Degree of coordination between countries | 2 | 5 |
| Effectiveness of control | 2 | 6 |
| Administrative burden | 2 | 3 |
| Technology transfer | 4 | 4 |

Table 1 does not list all relevant criteria for the comparison of the instruments, and there may be lots of different rankings even from a legislators and an individual agents perspective. But these criteria are some of the most important, and the rankings presented in the table may illustrate actual rankings:

The reasoning behind the rankings are the following: The legislators (the FCCC in case of green house gasses) primary concern are the environmental efficiencies of the instruments, because protecting the environment was the sole reason for the legislators to take action in the first place. If there is reason to believe that allowing JI or TP will undermine the environmental goals (for example undermine environmental goals expressed in international reduction commitments) – this may be too high a price to pay to obtain cost efficiency. The reason why JI and TP are interesting instruments are their cost efficiency property, but the reason why the cost efficiencies of the instruments only rank third to the legislators is, that the cost efficiency only is interesting to them if other criteria are fulfilled. The concern of the legislators are to secure the environment and to create the right administrative and institutional framework for the instruments. Given this, the individual agents (countries, firms, and others) may be expected to secure the cost effectiveness of the instruments through permits trading or joint implementation.

The individual agents primary concern is the cost ineffective instruments initiating JI or TP. How burdensome are for example the initial quotas? And with respect to TP, how is the permits distributed. The distribution of permits and the "design" of the instruments working as incentive for JI have great economic influence to the individual agents. Some of the negative economic influence can be eliminated through the cost effectiveness of JI or TP – if the administrative burden is not too large. The environmental effectiveness of JI and TP is only interesting to the individual agent if costs are linked to the environmental effectiveness:

JI accreditations may be directly linked to actual emissions reductions associated with concrete JI projects.

## Initiating the instruments

Both TP and JI presuppose other cost ineffective instruments, as indicated in table 2. Tradable Permits presuppose quotas, and presuppose an initial distribution of permits. The initial distribution of permits is one of the much discussed problems of TP, because of the economic significance to the "polluters". Different principles for distributing the permits – for example "grand fathering" or auctioning – affect the distribution of costs and the competitiveness of firms differently.

Joint Implementation may be initialised through several instruments. Table 3 describes different environmental instruments, and indicates whether these instruments can be used as incentives for JI and can coexist with JI. Table 3 shows that all the listed instruments can coexist with – and be used as incentives for – Joint Implementation. The incentives may not be equally strong though. The mechanism behind the incentives is that either taxes or (investment) costs can be avoided if Joint Implementation secure emission reductions elsewhere. If subsidies are given to specific emission reduction projects (for example within firms), these subsidies may alternatively be spent on more cost effective Joint Implementation projects. There is no need for coordination of the "initial instruments" between countries.

Whereas Tradable Permits and Tradable Quotas presuppose that all the participating countries have quotas, Joint Implementation can include in principle all countries.

**Table 2: "Secondary" environmental instruments**

| Secondary instruments | Short descriptions of the instruments | Presuppose other instruments as incentive? |
|---|---|---|
| Tradable Permits | Every single emission within the system demands an emission permit. Permits are traded on markets. The instrument works like an endogenous tax rate on emissions. | Presuppose quotas at, for example, the country level and presuppose initial distribution of permits. The distribution may follow different principles, for example, auctioning or "grand fathering". |
| Tradable Quotas | Direct trade with quotas or reduction commitments There is no system of permits (like in TP) and the traded emissions reductions are not necessarily tied to concrete projects (like in JI). | Presuppose quotas |
| Joint Implementation | Trade of emissions reductions/investments in foreign cheaper emission reduction projects. As only emission *reductions* are traded on the market, the amount of trades may be far less the amount of trades on the market for Tradable Permits. | Those who are supposed to engage in JI contracts must have an economic incentive to do it. Therefore the governments must be sure that the agents supposed to engage in JI are the agents that the instruments working as incentives for JI are "hitting". |

**Table 3: Primary environmental instruments and Joint Implementation**

| Primary instruments | Short description of the instruments | Can coexist with JI and be used as an incentive for JI? |
|---|---|---|
| Taxes or fees | Taxes on emissions, raw materials or the like | yes |
| Subsidies | Subsidies to for example emission reducing investments, preferred raw materials or preferred technologies | yes |
| Quotas | Quotas specifying the maximum level of emissions for for example firms, industries or countries | yes |
| Norms | Norms specifying for example the maximum emissions per produced unit. | yes |
| Technical standards | Specifying technical demands to the production technologies. | yes |
| Public cleaning | Public cleaning may be an option – if cleaning is possible (this is not the case with respect to CO2 emissions) | yes |
| Voluntary agreements | Voluntary agreements are agreements between the government and for example polluting industries about emission reductions, technologies, etc. | yes |

## How the cost efficiencies of the instruments are achieved

Figure 1 illustrate how the cost effectiveness of Joint Implementation, Tradable Permits and taxes are achieved. It shows, that in principle the three instruments may give the same cost effective solution, but it also illustrates that the mechanisms behind the cost efficiencies are different. The different mechanisms give rise to the different properties of the instruments.

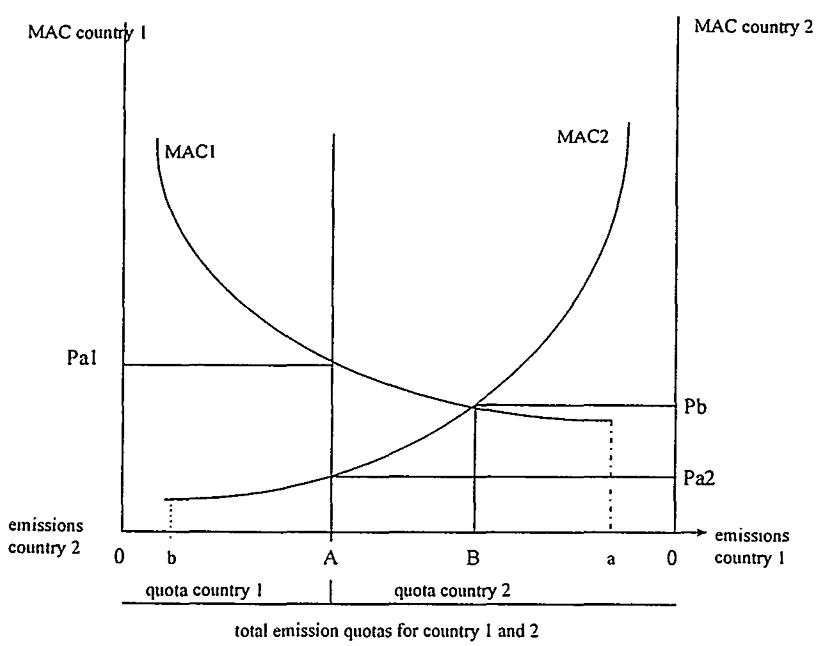


**Figure 1: Cost effectiveness of Joint Implementation, Tradable Permits and taxes.**

Figure 1 shows marginal abatement cost curves (MAC1 and MAC2) for two countries (1 and 2) with international emission reduction commitments equal to 0A and AB0. The countries marginal abatement cost are higher the lower the level of emissions. The line 0AB0 is the sum of the national quotas. The (initial) distribution of quotas implies marginal abatement costs in country 1 and 2 equal to Pa1 and Pa2 respectively. This difference in marginal abatement cost may be eliminated through coordinated taxes, or by allowing Joint Implementation or Tradable Permits. In theory all three instruments will deliver the same cost optimising result, namely the price Pb and the distribution 0AB and B0 of emission levels between country 1 and 2. But the mechanisms behind the cost optimising results are as previously mentioned different:

If the instrument is a coordinated tax on emissions, and the target level for total emissions are equal to 0AB0, a tax rate equal to Pb will deliver the desired target. Every single emitter has the opportunity of either investing in emission reductions and reduce his tax payments or to continue to pollute and pay the (full) emission tax.
The equilibrium is reached where marginal abatement costs are equal to the tax rate. If the marginal abatement cost curves are not known, it may be necessary to adjust the tax rate one or more times to reach the target level for total emissions.

If the instrument is Tradable Permits, country 1 and 2 distribute permits equal to their quota 0A and AB0 to the (domestic) emitters. Every single emission demands a permit. Every single emitter has the opportunities of buying and selling emission permits and either to continue to pollute or to invest in emissions reductions. The choice of the rational emitter will be to minimise costs/maximise profits. Cost minimisation will be reached where marginal abatement costs are equal to the price of the emission permits.

If the instrument is Joint Implementation, emission reduction projects are traded between the two countries. Lower marginal abatement costs in country 2 means that it is cheaper to invest in emission reductions in country 2 than in country 1. In a system with JI, county 1 invest directly in the concrete projects which lie behind county 2's marginal abatement cost curve. There may be different incentives to for example firms to engage in JI. But all who engage in JI may have the opportunity to invest in emission reductions in for example their own firm. If emission reduction projects are cheaper in other countries JI will be chosen.

Whereas Tradable Permits and the use of the tax instrument demands a coordination of the instruments between country 1 and 2, Joint Implementation needs no coordination: Only country 1 needs an incentive to engage in emission reduction projects in country 2.

In theory all tree instruments are cost efficient, and deliver the same distribution of emission levels But in practise, the instruments may be very different as the following sections will show.

## Cost efficiency

If the tax payers behave rationally, the tax instrument must be efficient with respect to costs.

If the agents behave rationally, the cost efficiency of Tradable Permits depends on the market structure for the permits – whether the competition on the market is perfect or monopolistic. Given rational agents and given a perfect competitive market, the TP instrument will be cost efficient.

The cost efficiency of joint implementation depends on choosing the right projects, i.e. the projects which will equate marginal abatement costs. This may not be a quite simple task:

One of the problems about an international agreement on Joint Implementation is to limit the amount of projects supplied to the JI market. There are huge numbers of projects which involve reduced emissions, but all these projects cannot be financed through JI and all the emission reductions cannot be assigned credit: Emissions reductions which are secondary effects of normal investment practise are free, and will be carried out despite of the JI financing. Therefore JI financing should not be given to this type of projects. There is no additional environmental effect, and therefore no cost reducing elements, in financing JI projects unless the JI projects are additional[1]. But if the JI projects are additional the environmental effects and the cost reducing effects of JI are maximised.

To sort out the additional projects baselines, cost curves, etc. pertaining the participating countries may be needed.

## Environmental effectiveness

Important problems relating to the environmental efficiency of taxes, TP and JI are: cheating, behaviour which will undermine the instrument, measurement problems (how big are the emissions, or the emission reductions) and leakage effects. Leakage effects means that emissions reduction in one place – firm, sector or county – are associated with higher emissions somewhere else: Polluting processes may be exported to countries without environmental regulations and the "polluting goods" be imported from these countries. The net effect to the environment is zero, but the exporting country will experience an emission reduction. Problems relating to the environmental effectiveness of each of the instruments are described below.

### *Taxes*

To obtain a specific environmental goal it may be necessary to adjust the tax instrument one or more times.

It is the individual taxpayer who cheats. And therefore it is the individual taxpayer who must be controlled, to secure the environmental effectiveness of the instrument.

The individual countries do not necessarily have an interest in controlling domestic tax payers. Therefore the international environmental authorities may have an interest in holding countries responsible for the environmental performance of the domestic polluters. But this may not be an easy task.

Leakages – export of expensive polluting processes, and import of cheap "polluting goods" – are results of the rational behaviour of the economic agents. And therefore leakages are a general property of the instrument. Leakage effects can only be traced when big/important firms are involved. Leakages are an environmental argument for international coordination of the tax instrument. The larger the group of countries coordinating the tax, the less the leakage problem. And the less foreign trade with countries outside the group of countries coordinating the tax, maybe the less the leakage problems – but trade patterns may change as a result of the common coordinated tax.

The coordination of the environmental tax is a way to reduce the individual countries free riding and competitive advantage of not taking action. Once the tax is coordinated, the individual countries may have an incentive to re-establish their original free rider or competitive position by trying to undermine the national effects of the tax. For example by

[1] Addtional projects are projects which would not have been carried out without the JI fianansing.

paying subsidies to the environmental tax payers, lowering other taxes or lowering the price of publicly regulated raw material prices. (A $CO_2$ tax on gasoline may for example partly be undermined by lowering other taxes on vehicles (the $CO_2$ tax may still have an effect of the marginal behaviour, but considering the economy of driving in own car to the alternative of using public transportation - the relative "over all" prices have not been changed), $CO_2$ taxes on the heavy energy intensive industries may be offset by heightening the subsidies for labour, capital, cheap loans, etc. with the consequence of easing some of the economic pressure for energy savings, and perhaps giving a competitive advantage to companies which are inefficient in energy terms).

## *Tradable permits*

It is the individual polluter who cheats, and therefore it is the individual polluter who must be controlled. The individual countries do not necessarily have an interest in controlling the domestic polluters.

Although the initial quotas was country specific, the individual countries can not be evaluated at a national level with respect to these quotas, because once the permit market is a reality the initial country specific distribution of the emission reductions will be changed. The international environmental authorities may have an interest in holding countries responsible for the environmental performance of the domestic polluters, but this may be difficult.

A positive price on emission permits implies that the level of emissions under a system with Tradable Permits will be equal to the total sum of quotas. This creates the "hot air" problem. The "hot air" problem describes a situation where a country's initial emission quota is not binding, for example because of negative economic growth. Without tradable permits this low emission level will benefit the environment, but in a system with tradable Permits, countries with binding quotas will buy emission permits from the countries without binding quotas and therefore the total level of emissions will equal the total level of quotas.

A dictator selling a substantial part of, or maybe all, emissions permits initially distributed to his country (because he do care about the environment, and thinks his country must show that there is a sustainable growth path) may undermine the system – unless this kind of behaviour is minimised.

Leakages are results of the rational behaviour of the economic agents. And therefore leakages are a general property of the instrument. Leakages can only be traced when big/important firms are involved. Leakages are an environmental argument for international coordination of the TP instrument.

## *Joint Implementation*

The environmental effectiveness of JI is very much dependent on whether the participating countries have binding commitments or not, and whether countries with binding commitments take these commitments serious.

With respect to countries with binding commitments (annex 1 countries) the biggest environmental problems are whether countries feel obliged to keep their international reduction commitments or not, and leakage problems. If countries do not take their commitments serious, or if some of the participating countries do not have binding commitments (non annex 1 countries) the biggest environmental problems are undermining the instrument, cheating, measurement problems and leakages.

If every JI contract implies the accept of the donor and host countries, and if these countries feel obliged by their international reduction commitments, then there is no environmental risks in opening up for JI arrangements: Some JI arrangements may give less emission reduction than expected for example because of cheating. But as long as the donor and host countries can be hold responsible for the emission reductions at the country level, then the success or failure of individual JI projects will not affect the environmental effectiveness of the JI instrument.

If one or more annex 1 countries do not feel obliged to keep their international reduction commitments, and if the use of JI in these countries is "problematic" it should in principle be possible to discover (by control at the country level) that something is wrong – at least after some years. Measures against the problematic countries, might increase the likelihood of these countries keeping their international commitments.

JI arrangements with countries which do not have international reduction commitments may be a serious environmental problem, unless heavily regulated. To secure the environmental efficiency of JI in these circumstances, it is necessary to sort out the additional projects by using baselines, cost curves, etc. And to impose heavy control. If the institutional framework for JI can be constructed in a way so the involved countries have incentives to secure the environmental efficiency of the instrument, this off cause should be implemented.

Because JI is related to concrete emission reduction projects it should – in principle – be possible to trace leakages back to specific JI projects. And to try to prevent accreditation of leakage effects. But it may be difficult in practice.

## The administrative burden

The burden of administration may differ between JI and TP, but it is difficult to make a comparison. Firstly because the administrative burdens will be very much dependent on the institutional setup of the two instruments, and secondly because there are many different administrative elements to evaluate. The administrative burdens may fall on the international environmental authorities, countries or individual agents. Some of the elements are: The degree of coordination between countries, the amount of control, the transparencies of the markets, the amount of information needed to trade on the markets, etc.

The administrative burdens in relation to JI may be very much dependent on whether JI arrangement with countries without binding commitments are allowed or not, and whether countries with binding commitments take their commitments serious or not.

## Conclusion

Table 4 summarises some of the issues with respect to evaluating Joint Implementation and Tradable permits as international environmental instruments. Both instruments use the market mechanism to eliminate cost inefficiencies, Tradable Permits through markets for emission permits, and Joint Implementation through markets for emission reductions. In practice the instruments are very different, as the table suggests.

**Table 4: Important issues with respect to evaluating the instruments**

| Criteria\Issues | Tradable Permits | Joint Implementation |
|---|---|---|
| Environmental effectiveness | "Hot air"<br>Leakage<br>Cheating | Do countries take their emission reduction commitments serious?<br>("Hot air")<br>Leakage |
| Cost effectiveness | Competitiveness of market | Selecting the right projects<br>Competitiveness of market |
| Initiating the instrument | Presuppose quotas<br>Distribution of permits | Presuppose cost ineffective instruments |
| Degree of coordination between countries | High<br>All participants must have binding commitments | Low<br>Countries which do not have binding commitment may participate – but this demands a high degree of control |
| Effectiveness of control | Control at the level of individual emitter.<br><br>Do countries have an incentive to control their own citizens? | Control at project level demands baselines etc.<br>Control at country level possible if countries have binding commitments.<br>Countries do have an incentive to control their own citizens if countries have binding commitments and take these serious. |
| Administrative burden | The organisation of the market.<br>Control. | The organisation of the market.<br>Selecting the right projects.<br>The accreditation procedure. |

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# JOINT IMPLEMENTATION AS AN OPTION FOR DEVELOPING COUNTRIES TO IMPROVE BARGAINING POWER

Two bargaining games for a global regime of emission trading in the Climate Convention.

*Paper presented at the 22nd IAEE Conference Rome June 1999.*

**Abstract:** An important purpose of the fourth meeting between the parties to the Framework Convention on Climate Change (FCCC) in Buenos Aires, November 1998, was to follow up on the so-called Kyoto mechanisms. These mechanisms include emission trading among industrialised countries and Joint Implementation between industrialised countries and developing countries - the Clean Development Mechanism (CDM). The CDM is a first attempt to institutionalise the participation of developing countries - it might not be the last. The USA, among others, has from the beginning of the FCCC negotiations argued for the need for developing countries participation and emission trading as an appropriate instrument. Economic theory shows that an international regime of emission trading may be in favour of the developing countries. This is due to this systems ability to combine and solve the burden-sharing problem and the cost-efficiency problem - in fact the developing countries might even obtain absolute gains from emission trading if the right quota allocation principle is used. Nevertheless it is the position of the G-77 to reject every step towards participation until the industrialised countries has shown that they are able and willing to fulfil their Kyoto targets on their own. This paper shows that while the CDM can be viewed as a way to make industrialised countries' commitments cheaper it could be used by the developing countries as a way to strengthen their bargaining power in quota-allocation negotiations. If the developing countries accept that they in the future will have to participate in international emission trading it would be optimal for them to start negotiations on a quota allocation principle immediately. This will enable them to use the supply of Joint Implementation projects to the CDM as an punishment option; if the industrialised countries fail to accept the developing countries quota allocation offer then they will be punished by a cut in the supply of CDM projects. The paper uses simple game theoretic modelling to show this relationship.

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# 1. INTRODUCTION

The United Nations Framework Convention on Climate Change was opened for ratification at the Conference on Environment and Development (UNCED) in Rio, 1992. The Convention divides the worlds countries in two groups. The so called Annex I countries, identical to the OECD countries and the countries with economies in transition (below denoted industrialised countries) are expected to cut emissions relative to a fixed target point to meet the objectives of the Convention. The non-annex countries, identical to a very broad definition of developing countries, are not supposed to cut emissions.

At the Kyoto meeting in 1997 the parties to the Convention agreed on a Protocol (the Kyoto Protocol) defining legally binding reduction commitments for the industrialised countries. Despite a continuous pressure from the so-called JUSCANZ[i] group the developing countries have succeeded in sustaining their unanimous no-commitment position. This position may not be everlasting. At the latest meeting between the parties to the Convention, in November 1998, the Host Country, Argentina, pronounced willingness to commit to a fixed emission target. This departure from the unanimous no-commitment position undoubtedly increases the pressure for participation from the rest of the group of developing countries.

The Kyoto Protocol opens up for the use of flexible mechanisms as Joint Implementation and emissions trading. In connection to participation from developing countries, article 12 of the Kyoto Protocol defines a mechanism (the Clean Development Mechanism, (CDM) for Joint Implementation between industrialised and developing countries. This means that the industrialised countries will be able to finance emission reductions in developing countries in exchange for reduction credits. The advantage of Joint Implementation is that it, under the assumption of relatively low abatement costs in the developing countries, is a cost-efficient way for the industrialised countries to fulfil their reduction commitments. The gains from the CDM, may be shared between the donor (industrialised) countries and the host (developing) countries by negotiating the amount of financial resources and emission credits transferred between the countries.

If other non-annex countries follow the pronouncement by Argentina, a global abatement regime may soon be implemented. A global regime of emission trading is likely to be preferred to other regimes such as command and control or international emission taxes etc.. An emission trading regime starts from an initial allocation of emission quotas that distributes the economic burdens connected to the emissions trading regime.

How initially to allocate the quotas in an emission trading regime has been discussed in the literature.[ii] The (non-tradable) emission quotas in the Kyoto Protocol are based on a non-uniform percentage reduction from 1990 emission levels. This means that the total emission quota, set to approximately 95% of the industrialised countries total 1990 emission level, is allocated such that the quotas for some countries only amounts to e.g. 92% of their 1990 emission level (for example the EU) while other countries have quotas exceeding 100% of their 1990 emission level (Australia, Norway and Iceland). One of the advantages of a non-uniform allocation rule is that it, at least in principle, can be cost-efficient. But with respect to the desirability of a cost-efficient distribution of quotas, it is important to notice that only the industrialised countries signed the Kyoto Protocol. Developing countries can be expected to have other views on allocation rules. The reason is that allocation rules based on cost efficiency would give them low allocations because: a) their 1990 emission levels are very low due to low economic development and b) their abatement costs are relatively low. The position of developing countries can more likely be expected to be based on a per capita view. The reason shall shortly be summarised.

One of the main arguments for developing countries participation is that these countries relative share of global emissions is rapidly increasing and is expected to exceed the emissions from industrialised countries within a range of 30 years time. Estimates show that developing countries' share of global annual emissions in 2025-2030 will be between 58% and 64%, i.e. larger than the industrialised countries.[iii] Other estimates show that the developing countries at the same time will be inhabited by more than 80% of the world's population. These figures and the need for economic development in the developing countries and their low share of accumulated emissions are used against the pressure for commitment. It would therefore be obvious that the developing countries would advocate for a per capita quota allocation as the basis for international emissions trading.

It seems that there are several reasons why developing countries may be in a potentially favourable bargaining position. The purpose of the following sections is to explore how this bargaining position can be used by the developing countries to increase their pay-off by looking at game theoretic descriptions of quota bargaining.

## 2. TWO QUOTA ALLOCATION BARGAINING GAMES

There are three basic assumptions behind the analysis in this section. First it is assumed that abatement costs are relatively low in the developing countries. Second it is assumed that the developing countries are relatively patient with respect to reaching an agreement on an allocation rule. And finally the developing countries are assumed to make the first move in the negotiations. Given these assumptions, we consider two bargaining games over the allocation of emission quotas between industrialised- and developing countries in a global regime of emission trading. The first two assumptions mentioned fits well into the description of the developing countries above, whereas the last assumption may be considered as normative. We show that JI may improve the developing countries' outcome of the bargaining.

## I. A simple quota bargaining game.

We will start by looking at a simple bargaining game where industrialised and developing countries bargain over the allocation of quotas given the total amount of emissions. There is no possibility of JI in this game. The two countries alternately propose an allocation leaving $x_{IC}$ to the industrialised countries and $x_{DC}$ to the developing countries. All the proposals must belong to the set of possible quota allocations defined by $X$. For convenience the total amount of emissions quotas are normalised to 1:

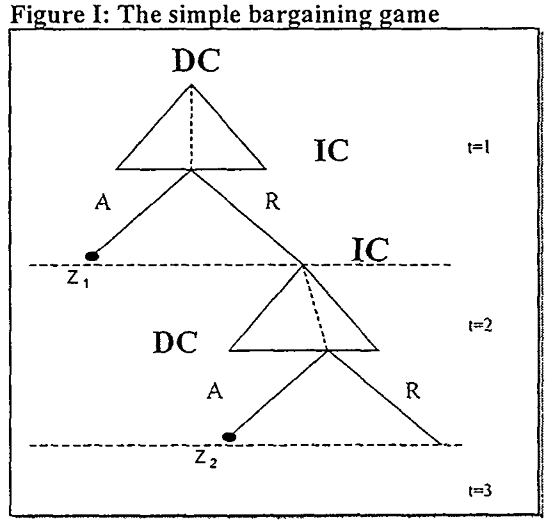
$$X = \{(x_{DC}, x_{IC}) \in \mathbf{R}^2 : x_{DC} + x_{IC} = 1 \text{ and } x_i \geq 0 \text{ for } i = \text{IC, DC}\}$$

After each proposal the opponent can either accept or reject. An allocation, $x_i$, at time $t$ gives player $i$ more utility than the same allocation received at time $t$+1. This time preference is incorporated in the utility function by a constant discount factor $\delta_i \in ]0;1[$. The utility function for player $i$ is

$$u_i(x_i, t) = \delta_i^{t-1} x_i, \quad \text{for } i = \text{IC,DC}$$

The assumption that the developing countries are relatively more patient with respect to when an agreement on the quota allocations is reached implies that $\delta_{DC} > \delta_{IC}$ : developing countries value future utility relatively higher than industrialised countries.

**Figure I: The simple bargaining game**




The structure of the bargaining game is shown in figure I. The bargaining starts in period 1 where the developing countries propose an allocation $x'$ within the set of possible allocations $X$. Figure I illustrates the proposed allocation by the dashed line reaching the bottom of the triangle. The bottom of the triangle illustrates $X$. Immediately after the developing countries proposal the industrialised countries shall either accept (A) or reject (R) the proposal. If they choose (A) the game ends with an agreement on $x'$ - if not the game proceeds to period 2. In period 2 the industrialised countries propose an allocation which the developing countries either accept (A) or reject (R). Acceptance ends the game and rejection makes the game proceed to period 3. In principle the game can continue like this in infinity. In the very simple game - given that each player knows everything about the other player and everything about the game, and given no uncertainty - an agreement will be reached in the first period of the game. This means that the allocation proposed by the developing countries can be accepted by the industrialised countries. We use a non co-operative solution concept where each player optimises his strategy given the other players strategy and where each player is able to reconsider his action at each point in the game. The game has a unique solution.[iv] Given perfect information each negotiator is well aware of the opponents' strategy. The unique solution gives, with the chosen utility function, an allocation where the developing- and industrialised countries receives

$$x_{DC} = \frac{(1-\delta_{IC})}{(1-\delta_{DC}\delta_{IC})}, \quad x_{IC} = \frac{\delta_{IC}(1-\delta_{DC})}{(1-\delta_{DC}\delta_{IC})}$$

Two conclusions can be drawn from the simple bargaining game. First of all the developing countries have an advantage of being the first to make a proposal, a so-called first mover advantage. To see this assume that $\delta_{DC}=\delta_{IC}=\delta$ such that there is symmetry in everything except who starts the game. This involves that $x_{DC} = \frac{(1-\delta)}{(1-\delta^2)}$ and that $x_{IC} = \frac{\delta(1-\delta)}{(1-\delta^2)}$, which clearly show that $x_{DC} > x_{IC}$, indicating that the developing countries get the largest allocation solely because they start the game. Secondly the developing countries has an advantage of being patient. This can be verified by noticing that $x_{DC}$ is increasing- and $x_{IC}$ is decreasing in $\delta_{DC}$. The opposite is true for increases in $\delta_{IC}$. Thus the more patient developing countries are (relative to industrialised countries) the larger the allocations they get.

Thus in the simple quota allocation game the developing countries will have the largest share of the total emission quota because they are the first to propose allocations and because they are relatively patient.

**II. A quota bargaining game which include Joint Implementation (the CDM).**
We will now enlarge the game structure in a way that further strengthens the developing countries bargaining power. In the simple bargaining game above we assumed that there was no possibility of Joint Implementation (CDM) between developing- and industrialised countries. In what follows we will assume that there prior to the quota bargaining exist an agreement which make Joint Implementation (CDM) between the two negotiators possible, and that this agreement is relevant for the bargaining. Even though an agreement of quota allocations will not be reached there will be an agreement of Joint Implementation, namely the CDM. The existence of an initial relationship, a reference agreement, between the negotiators adds new perspectives to the game. We will show that the reference agreement can improve the developing countries' bargaining power. In other words we will show that the CDM can be used strategically by the developing countries.

Denote the reference agreement (the CDM) by $x^0=(x^0_{DC}, x^0_{IC})$ where $x^0 \in X$. The CDM involves cost-efficient reduction of the industrialised countries' Kyoto commitments. The gains from this shall be shared between the host and donor countries by agreeing on the transfer of financial resources to the host and credits to the donor. If the gains from the CDM are normalised to 1 we face the same allocation problem as under the quota allocation bargaining. The share that the reference agreement allocates to the developing countries, $x^0_{DC}$, can now be thought of as gains from the CDM expressed in units of quota allocations. The developing countries utility from the CDM then exactly equals the utility from an emission allocation equal to $x^0_{DC}$, in a regime of emission trading. The same holds for the industrialised countries share of the reference agreement, $x^0_{IC}$.

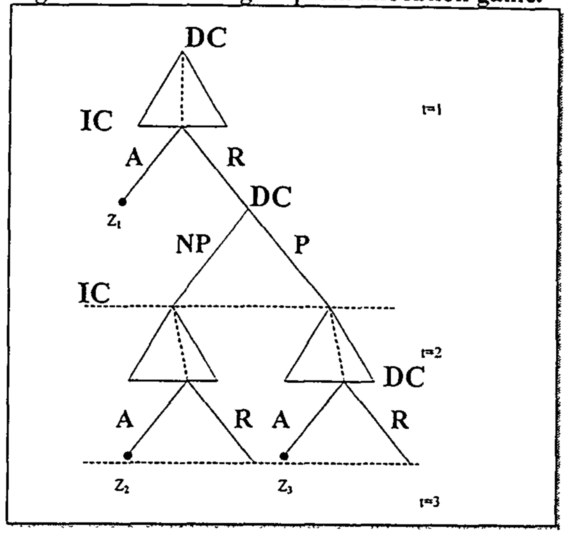
The presence of a reference agreement in quota bargaining means that the outcome is $x^0$ instead of 0 whenever a proposal is rejected. What it further means is that the negotiators can use the reference agreement as a potential threat because they can punish the opponent by withdrawing from the reference agreement if a proposal for a new agreement is rejected. This game structure is very common in the literature on wage bargaining between labour unions and firms.[v] In this literature a union and a firm bargain over the share of the firms revenue. The reference agreement is a wage $w^0$ for the union and a profit $1 - w^0$ to the firm (the firm's total revenue is normalised to 1 in the same way as we normalise the total amount of emission quotas). The union can now threat to withdraw from the reference agreement by going on strike. In every period the union strikes the firm will be restrained from obtaining the reference profit. An overall conclusion from the wage literature is that the union is able to gain larger wage by being able to go on strike. Basically it is the same idea that forms the ground for the game we are about to develop. We give the developing countries the opportunity to "go on strike" by cutting the supply of projects to the CDM and thereby restrain the gains from the reference agreement.

The outcome when the developing countries carries out the punishment is denoted by $x^s = (x^s_{DC,}, x^s_{IC}) \equiv (0, 0)$. The bargaining structure of the game is illustrated in figure II below. The bargaining structure is essentially the same as in the simple game. The only difference is that that the outcome in situations where a proposal is rejected can either be $x^0 = (x^0_{DC,}\ x^0_{IC})$ or $x^s = (0,0)$ depending on whether or not the developing countries choose to use the punishment option. The negotiators may on this background be thought of as maximising the sum of future utility

$$u_i(x_i, t) = \sum_{t=1}^{\infty} \delta^{t-1}{}_i x_i$$

whereas the maximisation of $u_i(x_i, t) = \delta^{t-1}{}_i x_i$ was sufficient for preference ordering in the simple game. Figure II illustrates that when a proposal is rejected the developing countries will make a choice of punishment strategy, where NP stands for No Punishment and P stands for Punishment. It can be shown that the optimal punishment strategy the developing countries can choose is to use the punishment option only when their own proposal is rejected, and therefore it is this case which is shown in the figure. The intuition for this asymmetric punishment strategy being optimal is straightforward. If the developing countries use the punishment option only when their own proposal is rejected and not when they reject the opponents proposal, rejection of their own proposal is made relatively more expensive. In this way they can force the industrialised countries to accept proposals more favourable to the developing countries. The game can in principle proceed in infinity, but like the simple game it turns out that optimal strategies lead to immediate agreement: the developing countries forms a strategy which results in their proposal on quota allocations being accepted in period 1. This result rests again on the assumption of perfect information and no uncertainties.

**Figure II: The enlarged quota allocation game.**




Where the simple bargaining game had a unique solution the present game where Joint Implementation (CDM) is a possibility has multiple solutions. Remember that the solution concept is non co-operative so that each negotiator takes the opponents strategy as given but is able to reassess his own strategy as the game proceeds. The most interesting solutions to the game is i) that $x^0$ - the Joint Implementation allocation - can be an outcome of the bargaining ii) that the agreement from the simple game $x'$ - where Joint Implementation was not taken into consideration - can be an outcome and finally that iii) it can be shown that there is a maximal quota that the developing countries can get as an outcome in the game structure. This maximal quota exceeds $x^0_{DC}$ and $x'_{DC}$. We denote the agreement leading to the maximal allocation to the developing countries by $x^*$ $=(x^*_{DC}, x^*_{IC})$. Obviously $x^0_{DC}$ (the Joint Implementation outcome) is the minimum allocation the developing countries can obtain because it is always possible to sustain status quo. It should further be noticed that it can be shown that every agreement leading to an allocation to the developing countries between the reference agreement $x^0_{DC}$ and $x^*_{DC}$ can be an outcome of the game. In other words, every $x \in ]x^0, x^*[$ is a possible outcome of non co-operative bargaining.

We will limit this paper to discuss the strategies leading to $x^*$ and will not go into details in explaining the existence of a maximal allocation, $x^*_{DC}$ (for details see [vi]).

It can be proved that, given the specific utility function we use, the largest possible quota allocation that the developing countries can achieve is expressed by:

$$x^*_{DC} = \frac{(1-\delta_{IC})}{(1-\delta_{DC}\cdot\delta_{IC})} + \frac{\delta_{IC} x^0_{DC}(1-\delta_{DC})}{(1-\delta_{DC}\cdot\delta_{IC})}$$

Notice that the first part of $x^*_{DC}$ equals the allocation in the unique solution of the simple game so that $x^*_{DC}$ obviously is larger than $x'_{DC}$. To achieve the largest possible allocation, $x^*_{DC}$, the developing countries' strategy include the punishment option previously mentioned, and a trigger strategy. The trigger strategy involves a (tacit) agreement with the industrialised countries to let the reference (Joint Implementation) agreement be an outcome in infinity if the developing countries defect from their overall bargaining strategy. Their overall bargaining strategy is to propose an allocation ($x^*_{DC}$) in the first period and make it clear that they will use the punishment option to cut the supply of Joint Implementation projects (CDM) if the industrialised countries rejects this offer. Furthermore their strategy must be never to use the punishment option in periods where industrialised countries are proposers. Remember that perfect information is an underlying assumption so that the industrialised countries are fully aware of the developing countries strategy and vice versa.

To summarise on the enlarged game we conclude that the developing countries can use Joint Implementation (CDM) strategically to increase their future quota allocation. By threatening the industrialised countries with a costly cut off of the supply of Joint Implementation (CDM) projects they can increase their own allocation on the expense of the industrialised countries.

## 3. DISCUSSION

In this section we will discuss the interpretation and plausibility of the maximal quota.

In the introduction we argued that it would be in the developing countries interest to take a per capita view on the responsibility pattern of the climate problem. In the bargains over future quota allocations one could therefore expect that the developing countries would propose to allocate the emission quotas on the basis of population size. Taking our game literally it gives an indication of the size of allocation the developing countries can expect to obtain in negotiation with the industrialised countries. An interesting question is on this background whether or not a population based allocation principle lies within the interval of possible outcomes predicted by the bargaining game.

In 1993 the world population was about 5,5 billion people.[vii] The population of the countries defined as developing countries in the Climate Convention was in the same year amounting to 4,3 billion people. In other words approximately 80% of the worlds population lived in the developing countries. More recent estimates of these numbers and projections of future world population levels will surely tend to increase this percentage share of people living in developing countries. Thus if the developing countries shall be able to obtain a quota allocation based on the level of population they shall be able to negotiate a division of the global emission quota that leaves more than 80% to themselves.

According to the equation above the maximal quota allocation $x^*_{DC}$ depends on the factors of time discounting and the level of the reference agreement $x^0_{DC}$. Under what assumptions on these parameters will a population based allocation proposal be obtainable as an outcome of negotiations? The table below calculates some scenarios.

The two first scenarios illustrate the first mover advantage. Assuming that the negotiators have identical time preferences the developing countries are able to obtain the relative largest allocation even without the existence of a Joint Implementation (CDM) reference agreement and the possibility of using Joint Implementation (CDM) as a punishment option.

**Table I: Scenarios for obtainable quota allocations.**

| Parameters | scenario 1 | scenario 2 | scenario 3 | scenario 4 |
|---|---|---|---|---|
| $\delta_{IC}$ | 0,90 | 0,90 | 0,90 | 0,90 |
| $\delta_{DC}$ | 0,90 | 0,90 | 0,99 | 0,99 |
| $x^0_{DC}$ | 0,50 | 0,30 | 0,50 | 0,30 |
| **Allocation** | **scenario 1** | **scenario 2** | **scenario 3** | **scenario 4** |
| Simple game $x'_{DC}$ | **0,53** | **0,53** | **0,92** | **0,92** |
| Enlarged game $x^*_{DC}$ | **0,76** | **0,67** | **0,96** | **0,94** |

This is shown by the fact that the allocation to developing countries in the simple game, $x'_{DC}$, is 0,53, leaving 0,47 to the industrialised countries. Scenario 1 assumes that the reference agreement are splitting the CDM gains on a fifty-fifty basis while scenario 2 more realistically gives developing countries a lower share of the CDM gains (30%). Scenario 2 is more realistic regarding the reference agreement because the main purpose of the CDM is cost-efficiency, which will be lowered the larger the financial transfers the developing countries receives in relation to the Joint Implementation projects. The industrialised countries can therefore be expected to have the largest share of the gains from the projects (above 50%). The enlarged scenario 1 - given identical time preferences and given the existence of a CDM reference agreement combined with the punishment strategy - will according to the table give the developing countries a maximum of 76% of the total emission quota. If the reference agreement only gives developing countries 30% of the CDM-gains, scenario 2 show that the maximal obtainable quota is 67%. Scenario 3 and 4 adds asymmetry in time discounting factor in scenario 1 and 2. By letting the developing countries time discounting factor be close to 1 it is assumed that these countries barely discount future utility and that they are patient relatively to the industrialised countries. The simple bargaining game now enables the developing countries to obtain 92% of the emission quota. The table shows that the possibility of using a punishment strategy is less important than in scenario 1 and 2, as it only raises the quota from 92% to 96% in scenario 3 where the reference agreement is equally split and from 92% to 94% in scenario 4 where the developing countries only gets 30% of the CDM gains.

What table I show us is that asymmetry in the time discounting is the most important aspect for the developing countries to obtain a large quota allocation. The possibility of Joint Implementation (CDM) as a punishment option is most important when the asymmetry in discounting factors is small or absent.

## 4. CONCLUSION

The present paper has discussed whether Joint Implementation between developing- and industrialised countries can improve the bargaining position of the developing countries in negotiations over quota allocations. The analysed mechanism is simply that the CDM can be viewed as an reference agreement, that enables the developing countries to form a punishment strategy. The conclusion is that the CDM can improve the bargaining position of the developing countries. It is worth noticing that this conclusion does not only apply to negotiations on quota allocations but to allocation problems in general. This means that if the international society (the FCCC) e.g. decides that the international abatement regime should include an international tax system where the tax revenue should be allocated between the countries the conclusion is still applicable.

## ENDNOTES

[i] The JUSCANZ group consists of Japan, US, Canada, Australia, New Zealand and Norway joined in 1997.

[ii] See e.g. Larsen, B. & A. Shah (1994) and Rose, A. & B. Stevens (1993).

[iii] Fenhann, J. (1998).

[iv] For a formal description and proof see Fernandez, R. & J. Glazer (1989) or Michelsen, M. B. & K.R. Olsen (1999).

[v] See e.g. Fernandez, R. & J. Glazer (1989), Haller & Holden (1990) and Shaked, A. & J. Sutton (1984).

[vi] For a comprehensive analysis we refer to Michelsen , M.B. & K.R. Olsen (1999).

[vii] All population estimates are from Fenhann, J. (1998).

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# WORKING PAPER

## Developing Countries in the Climate Convention.

## The Greenhouse Paradox

**Abstract.** *The Developing Countries (DCs) has a special position in the Climate Convention. While the Industrialised Countries (ICs) – following the Kyoto Protocol – are committed to reduce their emission of green house gasses the DCs are not. The DCs benefit from the abatement undertaken by the ICs, and this formally leaves them as free riders. The rationality behind free riding is the economic gain. But it is not obvious, which strategy will give the DCs the largest gain: To join the Climate Convention or to "free ride". The DCs free riding position may be a paradox.*

*This paper analyses the DCs "free riding" position in the Climate Convention and try to explain this position in a theoretical context. The upstream - downstream anlysis, and the Victim Pays Principle do not explain this position. The Polluter Pays Principle and the Hawk-Dove game can explain the different positions of the DCs and ICs. The Polluter Pays Principle may be based on moral rather than economic rationality.*

### Introduction.

Global warming is caused by the accumulation of so-called greenhouse gases (GHGs) in the atmosphere. These gases hinder the earth from giving off the heat absorbed from the sun. The concentration of GHGs in the atmosphere are popularly speaking 'building a greenhouse' around the earth. The consequence is that the mean temperature of the earth's surface is rising.

The stocks of the three most important GHGs – $CO_2$, $CH_4$ and $N_2O$ – have, since pre-industrial times (since about 1750), increased by about 30, 145 and 15 percent respectively. The $CO_2$ concentration is by far the largest of the three. The earth's radiative budget is measured in watts per square metre ($W\ m^{-2}$) and of the direct radiative forcing of the long lived GHGs (total 2.45 $W\ m^{-2}$) 1.56 $W\ m^{-2}$ (60%) is due to $CO_2$, 0.47 $W\ m^{-2}$ (20%)is due to $CH_4$ and 0.14 $W\ m^{-2}$ (6%) is due to $N_2O$. According to the IPCC the rise in the GHG concentrations is largely a consequence of human activities. The main source of $CO_2$ emission is burning of fossil fuels. For $CH_4$ the main emission sources are rice paddies, animal husbandry, landfills, biomass burning and for $N_2O$ the main sources are agriculture and biomass burning. (IPCC 1996a). Because the largest contribution to the rise in the concentration of GHGs comes from industrial fossil fuel burning the industrialised countries are carrying the main responsibility of the greenhouse effect.

The consequences of the greenhouse effect is projected in the climate models. Based on the GHG concentrations reported by IPCC Working Group I and the range of sensitivities of climate to increases in GHG concentrations, these models project an increase in global mean surface temperature of about 1-3.5°C and an associated increase in sea level of about 15-95 cm. (IPCC 1996c). Climate change influences eco-systems, agriculture and food production, human health, human infra structure and water resources management. Regional vulnerability increases as the adaptive capacity decreases. Because vulnerability of human health and socio-economic systems further depends upon economic circumstances and institutional infrastructure, developing countries are typically more vulnerable than more developed countries (ibid.).

The international society deals with the greenhouse problem in the UN Framework Convention on Climate Change (UNFCCC). The UNFCCC was an outcome of the Earth Summit in Rio 1992. The challenges it faces can be divided into the following tree levels:

**Level I:** The first, most superior, challenge is about sustainable development and *inter*generational distribution of wealth - i.e. distribution of wealth between generations. The question raised at this level is how much Greenhouse Gas emission (GHGs) the current generation can emit without disabling future generation's possibilities to sustain at least the same level of wealth. This question is actually not a main problem for social science but - maybe more for natural science. But the close dependency between emission of GHGs, industrialisation and economic development *makes* it to a problem that can be analysed by the tools from social science in general and economic theory in particular.

Models of economic growth have since the early 1970's dealt with the problems of sustainable development[1]. Comprehensive endogenous growth models, which make it possible to analyse the effects of economic- and environmental policy to the long run growth rates, have been developed[2].

**Level II:** The long run perspective at level I was the *inter*generational distribution of wealth. In the short run the *intra*generational distribution of the abatement cost - i.e. the distribution among countries in the current generation – is a problem of great concern. At this level the main question is how to implement the abatement needed to fulfil the purpose of sustainable development at level I. International environmental agreements like the Kyoto Protocol institutionalise these efforts for example by coordinating, implementing and suggesting instruments such as command and control, tradable quotas (TQs), joint implementation (JI), environmental investment funds and voluntary agreements.

The choice between these instruments is connected to issues such as cost efficiency, participation and free riding, burden sharing and environmental efficiency. What is wanted is a maximum of abatement at lowest possible cost (cost efficiency), but there may be other important objectives or demands, for example that the countries, which

[1] See e.g. Solow R. 1978, Dasghubta P. and G. Heal 1978. For a comparative analysis of these two papers, see Rose Olsen, 1993.

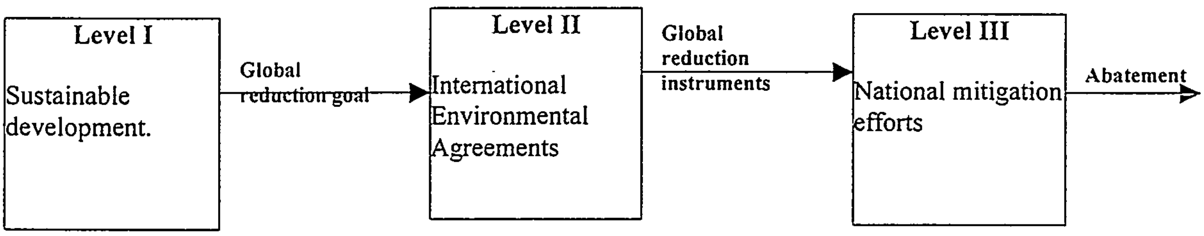
[2] See e.g. Smulders, S.A. (1995), Smulders, S.A. & A. Bovenberg (1995), Lighart J.E & F.van der Ploeg, 1994, 1995.

so far has been responsible for the increase in the concentration emission, must pay the largest share of the abatement cost. Moreover, the special characteristics of the greenhouse problem demand that as many countries as possible should participate in the abatement efforts (see below). If not, there is a risk that the effect of abatement from only a group of countries is being offset by increased emissions in other countries. This is the so-called leakage effects.

Game theoretic models are leading in the literature on the participation/free rider problems in international agrements[3], but these models have also been used to explore economic instruments such as JI and TQ[4]. Partial or simple general equilibrium models are used to study the instruments - especially taxes, TQ and JI[5]. Also applied work has been done on economic instruments[6].

**Level III:** This level deals with the national implementation of the international agrements'. The national governments have the same list of economic instruments available as the international authorities, but here the actors are firms, consumers, NGOs', environmental organisations etc.. At level III the questions are more related to the given country structural characteristics such as, level of economic development, sector analysis, main emission sources, level of privatisation and political system[7].

The present paper analyses level II. The diagram below summarises the '3 level-approach'.




The figure shows that the outcome at level I is a global reduction goal that must be institutionalised in an international agrement at level II. The outcome at level II is an agreed set of instruments, which the international society will use to reach the goal. Finally, these instruments must be implemented in mitigation efforts at the national level (level III). At level III the de facto abatement is carried out. What is important

[3] See e.g.; Barrett S. 1991, 1994a, Heal G. 1994, Carrarro C. and D. Siniscalco 1993, Carraro, C. and M. Botteon 1997a, 1997b for game theoretic analysis of selfenforcing international agrements. Hoel M. and K. Schneider 1997 for a game theoretic analyse of free rider incentives and JI.
[4] See e.g.;, Barrett S. 1993b , 1995 for game analysis of JI. Kaitala V. & Pohjola, M. 1991, Mäler K.G. 1989 for game analysis of the acid rain problem. Hoel, M. 1997d for game theoretic exploration of the TQ and international taxes in the Greenhouse problem
[5] See e.g.; Baumol and Oates 1988 for basic theory, Hoel M. 1997a,b,c for international taxes and TQ, Bohm P. 1992, 1994a, 1994b, 1997b, Bohm, P & Carlén 1997 and Bohm, P. & Larsen 1994 for TQ and JI analysis.
[6] See e.g.; Rose and Stevens 1993, Larsen, B. and A. Shah 1994, Halsnæs K. 1998 for applied analysis of TQ.
[7] See e.g. UNEP Collaborating Centre 1998 for guidelines for climate change mitigation assessment in DC's. Several country studies have emerged from these guidelines.

from this 'flow-figure' is that even though our focus will be on level II, and the economic instruments in international agrements, it must be keept in mind that these instruments must fulfil the goals from level I, and have to be implemented at level III. In other words the figure show that there is a large degree of interdependency between the tree levels.

## 1. International transboundary pollution

Some of the problems to the UNFCCC can be explained by the theory of international transboundary pollution. Because the Greenhouse Problem is caused by the accumulated amount of GHGs, and because the GHGs are pollutants with a global deposition, the economics of regulating emission of greenhouse gases may be seen as a special case of the economics of regulating international transboundary pollution. To see this, consider the following general equilibrium model (Based on Hoel 1997a;12-24)[8].

Consider a set of N open economies where the consumption in country $i$ is equal to production plus rents from capital stock, i.e.

$$c_i = f_i(k_i, l_i, e_i) + r(k_i^* - k_i)$$

where the capital $k$, labour $l$ and emissions $e$, are inputs in production, $k^*$ is domestic owned capital - hence if $k_i^*>k_i$ country $i$ earns rent. Domestic production is given by

$$x_i = f(k_i, l_i, e_i)$$

where employment, $l$, is assumed to be exogenously given. Emissions, $e$, are considered as input in the production, meaning that environmental resources, such as clean air, are used in the production. The function $f$ is homogenous of degree one and the derivates, $f_k$, $f_l$ and $f_{ij}$ are assumed to be positive. Production increases when the input of emissions increases. The derivative with respect to emissions, $f_e$, is assumed to be positive, if $e<e^0(k,l)$, or zero. $e^0$ is the emission level given by $f_e = 0$. Increasing the emission level above $e^0$ does not increase production.

Emissions increase production, but decrease the environmental standard. The transboundary environmental problem is characterised by, the dependensy of the environmental standard in country $i$ on emissions from other countries:

$$z_i = z_i\,(e_1, \ldots, e_j, \ldots, e_N) \quad \text{and} \quad z_e > 0.$$

where $z_i$ is the environmental variable and $e_j$ is the emission from country $j$. There are as noted above $N$ countries. Assume that the relationship between the vectors $z$ and $e$ are linear so that $z=Ae$, where $A$, is the so-called transportation matrix. An element of the transportation matrix $a_{ij}$ refers to the amount of emission from country $i$ that result in environmental damage in country $j$ - hence an increase in emissions increases $z$ and decreases the environmental standard.

[8] Equations are all taken from Hoels example. The model was originally studied by Oates and Schwab 1988.

A pareto optimal allocation of capital and emissions – from an international social planners view – solves the following:

$$\max_{k,e} \Sigma_i \alpha_i u_i(c_i, \Sigma_h e_h a_{hi}), \text{ where } u_c > 0,\ u_z < 0$$

s.t. $\Sigma_i c_i \leq \Sigma_i f_i(k_i, l_i, e_i)$ and

$$\Sigma_i k_i \leq \Sigma_i k^*_i$$

Where $u_i$ (.) is the utility function of country $i$ and $\alpha$ is a parameter larger than zero. The utility of country $i$, depends on the national level of consumption $c_i$ and on the amount of pollution that influenses its own environment. $\Sigma_h e_h a_{hi}$ is the sum of the pollution from other countries (and country $i$ itself) that ends up in country $i$.

The maximisation problem represents a choise between consumption and environmental standard.

Utility is maximised subject to appropriate limitations on consumption and capital; the sum of the countries consumption cannot exceed the sum of production $(f(k,l,e))$ and the sum of capital used as input may not exceed the sum of domestic owned capital $k^*$. Assuming that $k^*$ and l are exogenously given, maximisation leads to the Pareto conditions below:

(*) $$f_{1k}(k_1, l_1, e_1) = \ldots = f_{Nk}(k_N, l_N, e_N)$$

(**) $$f_{ie}(k_i, l_i, e_i) = \sum_j a_{ij}\left(\frac{-u_{jz}}{u_{jc}}\right) \quad \forall i$$

The first equation (*) show that the marginal product of capital used within the countries are equalised among countries. The second equation is more interesting. The left hand side show the marginal product of emissions (remember it is positive). The marginal product of emissions in country $i$ can be interpreted as the marginal *abatement* cost in that country $i$. This is a consequence of the way the production function is constructed: removing (or abating) one unit of emissions will cause the production to fall by $f_{ie}$, and this may be interpreted as the abatement cost. On the right hand side $\frac{u_{jz}}{u_{jc}}$, the marginal rate of substitution between consumption and environmental standard in country $j$, can be interpreted as the marginal costs in utility terms in country $j$, when consumption (and emissions) increases and the environmental standard decreases (remember that $u_z<0$). $a_{ij}$ is the coefficient of emission from country $i$ to country $j$. The right hand side is equal to the sum of the marginal costs in utility terms from one unit increase in emissions in country $i$.

The solution to the international social planners problem is hence that each country uses emissions in the production up to the point, where the marginal product of emissions are equal to the sum of the marginal costs. Or expressed in another way: that each country abates until marginal abatement costs equals the sum of marginal environmental benefit.

The decentralised (or non-co-operative), national solution to the maximisation problem is (see Hoel 1997; 13):

$$(***) \qquad f_{ie}(k_i, l_i, e_i) = a_{ii}\left(\frac{-u_{iz}}{u_{ic}}\right) \quad \forall i$$

which means that country *i* will choose to emit up to the point where the marginal benefits are equal to the country's own marginal costs. Or, the country will choose to abate until the marginal abatement costs in country *i* equal the country's own marginal environmental benefit. Obviously the non co-operative abatement level is lower than in (**).

The special characteristic of the GHG problem means that all elements in the transportation matrix equals 1, because the environmental cost are the same no matter the origin of the emissions (GHGs are uniform pollutants).

An optimal international agrement with respect to the climate problem would hence involve the implementation of (**), where $a_{ij} = 1$. The international regulation needed for that special value of $a_{ij}$ is relatively simple, because $a_{ij}=1$ imply an optimal abatement regime, where marginal abatement costs are the same in all countries.

An international optimal emission tax would be equal to:

$$t = \sum_j \left(\frac{-u_{jz}}{u_{jc}}\right)$$

which means that it should be a uniform tax rate. With respect to tradable emissions permits it means that these can be traded on a one for one basis - i.e. the value of an emission unit in country *i* is equal to the value of an emission unit in country j (see e.g. Baumol and Oates 1988; ch. 12 for analysis of emission trading where permits can *not* be traded on a 1:1 basis).

Regulating uniform pollutants is however a problem because it demands a *global* agreement. Other transboundary environmental problems, as e.g. the acid rain problem, can be solved by bilateral or regional agreements (but have the problem of being caused by non uniform pollutants where transportation coefficients are not equal to 1 [9]). The problem achieving the optimal solution given by (**) is that each country would be better of if it enjoys the gains from other countries abatement, while itself only abates according to (***). In other words each country has free rider incentives. The major problem with free riding is that the abatement, undertaken by the international agrement, will be lower than the optimal level indicated by (**), because some countries (the free riders) will only undertake abatement as indicated by (***)[10].

[9] See e.g. Mäler 1989 and Katiala and Pohjola 1991 for studies of the acid rain problem where regional and bilateral agreements are used.

[10] There are of course other problems connected to reaching the optimal solution. For discussions on second best solutions See e.g. Baumol & Oates (1988) or Hoel 1997a; 14-15)

*Because climate change is caused by uniform pollutants an optimal agreement demand global participation. As a consequence the climate problem is more exposed and vulnerable to free riding.*

Another problem connected to free riding is the already mentioned leakage effects. Free riding arises when countries, that benefit from global abatement, do not contribute to the abatement. Leakages arise when abatement by the co-operating countries leads to increased emissions in the non co-operating countries. Leakage effects reduce, and maybe offset, the environmental impacts of the cooperating countries abatement. Leakage effects most often arise through trade effects – for example shifts in prices, comparative advantages and world demand on carbon intensive products – and may therefore be reduced through trade policies. Leakages based on co-operating countries net-import of carbon intensive goods from non cooperative countries, may be reduced through appropriate tariffs (positive or negative) (Hoel 1994, 1997a; 30-34, Barret 1994b; 12-23). It may, however, be a problem to use trade policies to reduce leakages. First of all, because it might be in conflict with WTO rules, and second because it might be undesireable to use this policy, because the non-participating countries are DCs, who are especially vulnerable to trade restrictions.

The evidence on leakage effects are rather blurred, and while some studies result in leakage rates of 70-80% (Pezzey 1992), other result in leakage rates of only 1,4 - 11,9% (Oliveira-Martins et al. 1992). Nevertheless, the IPCC determines leakage as a potential serious problem (IPCC 1996b; 425).

The Kyoto Protocol is subject to free riding, or limited participation, because the so-called annex I countries, which are identical to the Industrialised Countries (ICs), are committed to fixed emission reduction targets and abatement, while the so-called non-annex I countries, which are identical to the Developing Countries (DCs), are not committed.

Free riding in international environmental agreements (IEA) is a situation where a country: *'receive the benefit of the other country's abatement without having to incur abatement costs itself'* (Barrett, 1992a; 73). Relating this definition to the Kyoto Protocol, where only ICs are committed, and where the benefits from the abatement efforts is a "global public good", leaves the non-committed DCs as de facto free riders. The problem with free riding is that it results in less than optimal abatement, a) because the free riding countries are not internalising the externalities, and b) because leakage effects may arise.

The term 'Limited participation' is often used to define the situation that not all countries join an international agreement and therefore this definition more directly covers the DCs position in the UNFCCC because these countries do not join the Kyoto Protocol. The problem with limited participation is again that it results in less than optimal abatement and leakage effects. The above definition of free riding is thus identical to the definition of limited participation.

The rest of the paper is organised as follows. Section 2 will describe the free riding situation in the UNFCCC. The current free rider situation is defined as a paradox; the greenhouse paradox. Section 3 will analyse free riding in connection to the theoretic frameworks most often used to analyse this phenomenon.

## 2. Free rider incentives in the UNFCCC

This section specify the different aspects of the free riding situation in the UNFCCC. By illustrating the responsibility asymmetries resulting from differences in past, current and future emissions, section 2.1 analyse the moral aspect. Section 2.2 describes the political split between the ICs and DCs by sketching the negotiation history of the UNFCCC, the implicit inclusion of the polluter pays principle in the convention text and the main standpoints of the most critical DC actors. Section 2.3 determines the free rider situation in a game theoretic context and argue that this situation cannot be a stable equilibrium unless specific assumptions are made.

### 2.1 UNFCCC and responsibility.

The greenhouse effect is caused by the accumulation of GHG's - therefore responsibility measures have to look at cumulated GHG emission. This section will make clear that the responsibility pattern change over time, by looking at past, current and future emission from the ICs and the DCs.

*Past emission .*

Estimates of past $CO_2$ emission show a clear tendency. First of all the emission data show a sharp rise in emissions after the industrial revolution. Since then a large proportion of the increase in emissions originated from the burning of fossil fuels. As a consequence it is the industrialised countries that are responsible for the largest proportion of the GHG accumulation. Estimates of the cumulated $CO_2$ emissions from 1860-1986 show that ICs are responsible for 86% of the increased emissions, and DCs for 16% – if only energy sources are looked at. If biota are included, the ICs are responsible for 68-80% of the cumulated $CO_2$ emissions, and DCs for the remaining 20-32% (Subak, 1994;59). In this perspective there is no doubt that the historic responsibility lies on the shoulders of the industrialised countries. This clear historic responsibility of the ICs means that the UNFCCC address the need for IC leadership. More will be said about this in the section 2.2.

*Current emission*

Estimates of current emissions are much more comprehensive than past emissions, and it is possible to include other GHG's than $CO_2$. The commitments of the annex I countries cover (according to article 3 and annex A of the Kyoto Protocol) emissions of 6 GHG's from 5 sectors. The 6 GHGs are the following of which we will limit the analysis to the first 3.

- Carbon Dioxide ($CO_2$)
- Methane ($CH_4$)
- Nitrous oxide ($N_2O$)
- Hydrofluorcarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride ($SF_6$)

When more than 1 GHG is included in emission estimates one needs to convert the different gases to a common unit. Working group I of the Intergovernmental Panel on

Climate Change (IPCC) calculate the so-called Global Warming Potentials (GWP) which can be used to convert emission estimates into $CO_2$ equivalents. Throughout the section we use the 100 years time horizon which means that $CH_4$ estimates shall be multiplied with 21 GWP and $N_2O$ shall be multiplied with 310 (IPCC 1995a; table 2.9)

As an indication of some of the consequences of including more than $CO_2$ in the estimates we can look at the distribution of emission between DC' and ICs in 1993 in table 2.1.1.

If only carbon dioxide is included, the distribution is 49% for DCs and 51% for ICs. If we include $CH_4$ and $N_2O$, this allocation will be reversed so that DCs now account for 51% of total emission. This is mostly due to a relatively large emission of methane from the agricultural sector in the DCs. In a responsibility perspective it therefore does not seem favourable for the DCs that all three GHG's are included. This is because the DCs responsibility is larger, and because it could give arguments for more comprehensive commitments to the DCs (or lower initial quota allocations in a TQ regime). (What is favourable to the DCs is also dependent on the future development of each of the tree gasses).

As seen from table 2.1.1 the exclusion of landuse change and forestry is crucial to the distribution of emission between ICs and DCs. If we extract landuse change and forestry from the pure $CO_2$ case, the DCs only account for 36% of global emission compared to 49% when it is included. If we do the same extraction from the case with three GHG's the DCs share falls from 51% to 41%. This indicates that it ceteris paribus could be in the interest of the DCs that forestry is excluded in emission estimates, and that only $CO_2$ is included, because this would give them relatively low responsibility, and therefore low commitments or large initial quotas.

**Table 2.1.1 Relative share of emission in 1993**

| | 1993 | |
|---|---|---|
| | Non-annex countries (DC) | Annex I countries (IC) |
| CO2 | 49% | 51% |
| $CO_2$, $N_2O$, $CH_4$ | 51% | 49% |
| $CO_2$ excl. forestry | 36% | 64% |
| $CO_2$, $N_2O$, $CH_4$ excl. forestry | 41% | 59% |

Source: calculations based on Fenhann (1998)

The table indicates that there is a significant degree of convergence in current emissions compared to past, but it is much affected by the choice of GHG's and sectors. Still it should be remembered that it is the accumulated emissions that reflect the responsibility pattern, and that the DCs need allowances to higher emission rates to converge to the same level of wealth as the ICs.

Emissions per capita has been proposed as another responsibility measure. In 1993 the world population were about 5,5 billions of which the 4,3 billion lived in the DCs. This means that almost 80% of the world population lives in the DCs and leaves the reduction responsibility on the ICs.[11]

[11] The population estimates are taken from Fenhann (1998)

*Future emissions.*
It must be expected that DCs emissions, because of increasing economic growth rates, will rise in the future. At the same time the emissions from the ICs will tend to fall because of the efforts to fulfil their commitments in the Kyoto Protocol. Fenhann (1998) has estimated future emissions of $CO_2$, $N_2O$, and $CH_4$ from ICs and DCs respectively[12]. The DCs' and ICs' relative share of emissions are shown in table 2.1.2 below.

**Table 2.1.2 Relative share of emission in 2020-25**

| | 2020-25 | |
|---|---|---|
| | **Non-annex countries (DC)** | **Annex I countries (IC)** |
| **$CO_2$** | 64% | 36% |
| **$CO_2$, $N_2O$, $CH_4$** | 64% | 36% |
| **$CO_2$ excl. forestry** | 58% | 42% |
| **$CO_2$, $N_2O$, $CH_4$ excl. forestry** | 58% | 42% |

Source: calculations based on Fenhann (1998)

The table shows that no matter which of GHG's and sectors that is included, the DCs has the largest share of total emission. At the same time there is no longer a difference between the case where only $CO_2$ is included and the case where all three GHG's are included. This is largely due to a convergence of emission patterns.

The convergence pattern is explained by the facts that compared to the 1993 emission pattern the DCs has increased the share of $CO_2$ emission from the energy sector while the share of $CH_4$ emissions from the agricultural sector, which is the second largest, has fallen. The opposite is true for the ICs; falling importance of $CO_2$ emissions from the energy and risen importance of $CH_4$ from the agricultural sector (see Fenhann 1998 figure 2-4).

Excluding forestry still lowers the DCs share of total emission but again it does not matter whether only $CO_2$ or all three GHG's are included. The 2020-25 emissions are partly due to the expected rise in world population of 2,4 billion people of which the 2,1 billion in the DCs[13]. In a per capita view the responsibility therefore still rests on the ICs.

Responsible for more than 50% of annual global emissions, it is however inevitable that the DCs will have to participate in future emission reduction efforts, if the greenhouse problem is to be solved.

## 2.2 The Free riding situation in the UNFCCC

This section summarises the negotiation history of the UNFCCC, and summarises the climate policies of some of the important DC actors.

*The UNFCCC history*
The UNFCCC where opened for ratification on the Earth Summit in Rio 1992. In 1994 it was ratified by fifty nations and was then taken in to force. Basically the UNFCCC consists of 'one objective for emission reduction, three principles for

[12] The estimates are based on a assumption of medium population growth (Fenhann 1998; 13)
[13] These population estimates are from Fenhann (1998) and is used in his estimates of future emissions.

climate policy, five permanent institutions and the recently agreed Kyoto Protocol' (Børsting, G. and G. Fermann, 1997).

The objective of the UNFCCC is stated in article 2 of the convention as: '*stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.*' (UNFCCC 1997a; art. 2 ). In the Kyoto Protocol this objective has been made operational by binding reduction commitments.

Article 3 of the convention defines three principles for the global action against climate change: Firstly the precautionary principle, which defend taking action despite the uncertainty connected to the greenhouse effect. Secondly the principle of cost-effectiveness take '*into account that policies and measures to deal with climate change should .... ensure global benefits at lowest possible cost*' (ibid. ; art. 3.3). Thirdly the principle of equity is addressed to secure awareness of the different responsibilities and capabilities among parties. In this way paragraph 1 in article 3 states that '*Accordingly, the developed country Parties should take the lead*' (ibid. ; art. 3.1) and paragraph 2 defines the vulnerable situation for DCs by '*especially those (countries) that are particular vulnerable to the adverse effects of climate change, and those Parties, especially developing Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration.*' (ibid. ; art. 3.2).

The five permanent institutions are i) The Conference of the Parties (CoP) which is the decision making body of he Convention. ii) The Subsidiary Body for Scientific and Technological Advice (SBSTA) made responsible for the provision of timely information and advice on scientific and technological matters. iii) The Subsidiary Body for Implementation (SBI) with the purpose of assisting the CoP in its assessment and review of the implementation of the Convention. iv) The UNFCCC Secretariat made permanent by the CoP-1 session and, finally, v) a financial mechanism for the provision of financial resources based on grants or concessionaire financing working through the Global Environmental Facility (GEF).

Since ratification in 1994 four sessions in the decision making body, CoP, has been undertaken. The CoP-1 meeting took place in Berlin in 1995. The most important outcome of this session was the Berlin mandate. With the Berlin mandate it was agreed that the current emissions reductions were inadequate if the greenhouse effect were to be stabilised - commitment were found to be needed. Furthermore it was agreed that developing countries should be free from obligations to reduce emissions. A negotiation group; the Ad hoc Group of the Berlin Mandate (AGBM), were established with the purpose of finishing the negotiations of reduction commitments before the end of 1997.

The CoP-2 meeting took place in Geneva in 1996 and may be seen as an interim negotiation. In Geneva the main outcome were the 'Geneva declaration', where it was confirmed that the AGBM should aim at a legally binding protocol or another legal instrument pursuing objectives for emission limitations within certain time frames.

The success with agreeing on the aim at legally binding commitments came through due to the shift in position from the USA. USA supported for the first time legally binding commitment on the conditions that 'activities implemented jointly' and emission trading were to be part of any future regime (Børsting, G. and G. Fermann; 1997).

The 8th meeting in the AGBM were held in October 1997 and this was the final call for the parties to set out negotiation objectives for binding emission reductions. The main bargaining arose among the EU and the USA which started out with very different ambitions. The EU proposal was to reduce emission 15% below 1990 level in 2010, while the USA proposal were less ambiguous; only to stabilise emissions at 1990 level in 2008-2012. Furthermore the USA demanded that the DCs should commit as well. Just before the CoP-3 session in Kyoto a negotiation text where agreed upon in the AGBM and hard negotiation followed.

The CoP-3 session in Kyoto in November 1997 succeeded in reaching an agreement on a protocol defining legally binding commitments for the annex I countries. The ambition were however not that compelling: to reach an emission level 5% below 1990 level within 2008-2012. The obligations were distributed non-uniformly among the annex I countries, such that some countries should reduce by e.g. 8% below 1990 level (e.g. the EU) while others were allowed to increase their emission (e.g. Norway). The discussions on joint implementation and emission trading were largely removed to be solved in the CoP-4 session in Buenos Aires, but by a proposal by USA and Brazil the Clean Development Mechanism were defined in article 12 of the Protocol.

The CoP-4 meeting in Buenos Aires laid down an action plan for the negotiations leading to definition of rules for the flexible mechanisms. Negotiations has to be completed before the CoP-6 meeting in 2000. In this way it could be argued that the CoP-4 meeting share the interim negotiation perspective with the CoP-2 meeting. The political willingness to flexible mechanisms may be seen as strengthened during the CoP-4 sessions, but final decisions were as noted moved to 2000.

*The DCs' political position.*
To further describe the free riding position of the DCs the political positions on climate change for some of the leading countries in the G-77 will shortly be summarised.

The group of non-annex countries is covering countries at very different levels of economic development. In connection to the free rider deterrence perspective three non annex developing countries are obvious candidates for individual investigation; China, India and Brazil. This is first of all because they individually are relatively large emitters and second because they have all played a central role in shaping the position of the group of DCs - the G-77.

The developing countries are formally united in the so called G-77 grouping formed in 1960 in preparation for the UN Conference on Trade and Development. Even though China is not formally a member of this group drafts from the group has, due to China's huge size and influence in world politics, typically been on the behalf of 'G-77 and China'. In practice however the G-77 grouping is divided into subgroups such as semi-industrialised-, oil producing- and small island countries because of the relatively large differences among the member countries. The semi-industrialised group included initially the three large countries: China, India and Brazil, but during the negotiations of the International Negotiating Committee preparing for the UNCED in Rio 1992 the group was split because of leadership-struggles. Still China and India is combating on the question of who should lead the group (Beuermann, C. 1997).

*China*

Before the Rio 1992 meeting China hosted a Ministerial Conference of Developing Countries on Environment and Development that resulted in the Beijing declaration. This declaration stated the need for differentiated responsibilities between developing and developed countries, and stated that the latter must provide adequate technology transfer and financing (IEA 1995/96; 43). In the Climate negotiation as well as in negotiations of other international environmental problems China is thus one of the leading developing countries advocating the need for diversified responsibility.

The climate change characteristics of China can shortly be defined by 6 factors:

- very high total emission level and very low emission level per capita
- 'no commitment' policy
- extremely low energy efficiency partly because relatively low energy prices
- coal as the current main source and because of huge reserves also in the future
- political awareness of the responsibility of the industrialised world and ambitions to lead the group of developing countries
- relatively high vulnerability to global warming, but with regional differences.

The 'no- commitment' policy is a key factor and can be explained mainly by the Chinese awareness and focus on the responsibility of the industrialised world (grounded in a polluter pays awareness) and on the Chinese goal of using the country's natural resources in promoting economic development and environmental goals as stated in the Beijing declaration. Commitments is, in this perspective, seen as conflicting with national sovereignty and is because of this - and because of lack of financial resources - neglected (ibid.).

*India*

India can be characterised as a country with relatively high emissions of greenhouse gasses but very low per capita emissions. The Indian position on climate change is extremely based on the awareness of the ICs responsibility, and on the need for a per capita view on burden sharing. But because the most dominant national concerns are on poverty alleviation, population growth and employment a national climate strategy is rather absent. (Jacobsen, S. 1998).

*Brazil.*

In the greenhouse debate in the 1980's, Brazil was thought of as the really 'bad guy' because of the deforestation of the amazon jungle. The amazon was largely regarded as the 'lounges of the earth' and as the factual cause of the greenhouse effect. It later appeared that the consequences of the Brazilian deforestation was largely exaggerated (Kasa, S., 1997), but this old debate continues to be one of the main characteristic of the Brazilian position in the global warming problem.

It has been argued that there has been a clear-cut shift in the Brazilian position on climate change (ibid.), but nevertheless focus has always been on the responsibility of the industrialised countries. During the last decades the Brazilian position on climate change has been softened, both because of shifting governments, but also because of the ongoing democratisation process that shifts the power away from the military that have a strong interest in the Amazon region. The military see deforestation of the amazon as a security factor because cutting forest in the border regions is the only way to monitor the borders. As a consequence they are strong opponents of limitations in the rights to cut forests.

### 2.3 Defining Free riding in the UNFCCC

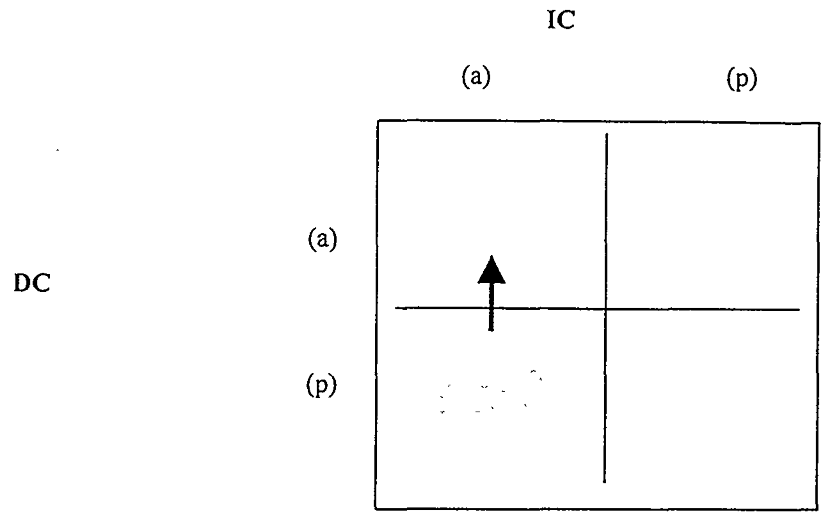
Dividing the parties of the UNFCCC into two main groups, the annex I countries – identical with the Ics – and the non-annex I countries – identical to the DCs – leaves the last as free riders in a limited participation definition.

One free rider argument is that the DCs are not responsible of the current problem of global warming and hence are not morally obliged to undertake abatement. This position could be justified from section 2.1 on responsibility – at least if the per capita perspective was taken. It could also be justified from the text of the UNFCCC quoted in section 2.2. Especially article 3 in the Climate Convention stated a clear awareness of the ICs responsibility to take the lead. The article actually indicates an implicit adoption of the polluter pays principle in the UNFCCC. In the climate case, this principle states that the actors who emits GHG's, must finance the abatement needed to slow down the accumulation of GHGs. The polluter pays principle (PPP) was first indicated in the Stockholm Conference in 1972 and adopted by the OECD as a guideline for domestic environmental policies the same year (Mäler 1992; 409). The application to international environmental problems is straightforward and the principle has been presumed in most international environmental conventions since (ibid.; 410). Article 3 in the UNFCCC and the free rider 'allowances' in the Kyoto Protocol indicates that the PPP also is presumed in the Climate Convention.

Another reason for DCs to free ride is connected to the large asymmetry among ICs and DCs. Because the DCs economies are less developed and hence more vulnerable to the cost of undertaking abatement, participation in the Kyoto Protocol might weaken their ability to improve their level of development, or even their possibility to fulfil basic human needs.

Studies of free riding are often modelled in a game theoretic context and for later use we find it convenient to define the free riding situation in the UNFCCC by the following game theoretic illustration. Figure 2.3.1 show a strategic game box where the two players are the ICs and the DCs. There are two possible policy actions: Abate (a) or pollute (p). Acting strategically, each of the two players will try to maximise his/her own payoff taken the opponents strategy for given. The outcome of such strategic interaction is the so-called Nash equilibrium.

**Figure 2.3.1 The Greenhouse Paradox.**




According to the analysis in this paperr the current negotiation situation is to be found in the lowest left hand box (shaded). This defines a situation where the ICs are abating and the DCs are polluting. Because the DCs enjoy the gains from ICs abatement they can be defined as free riders. To solve the free riding (limited participation) problem is to induce the DCs to participate in abatement efforts. In figure 2.3.1 this is indicated by the arrow - i.e. a movement from the present situation where DCs play (p) and ICs play (a) to a situation where both play (a).

The problem is that such a movement seems to be impossible because of the political and moral factors defining the DCs position. In traditional game theoretic studies a movement to the (a,a) situation can fail to incur, either because it will not be pareto improving or because it is an unstable situation. With respect to the UNFCCC (a,a) could indeed be unstable, because both parties would be better off (in economic terms) if s/he polluted, and at the same time gained from the other parts abatement efforts.

But how do we explain the fact that the ICs seem to accept the present (p,a) situation? The situation can hardly be an equilibrium based on economic rationality arguments because ICs are characterised by both relatively high cost and low damage? The (p,a) situation may be defined as a paradox, that cannot be explained without including the PPP in the economic analysis.

The definition of a Pareto improvement is: A movement that leaves at least one part better off and no-one worse off (compared to the initial situation).

According to the DCs political standpoint, they find themselves worse off if they at present are forced to abate – hence this cannot be pareto improving. But according to findings in many studies, a global regime of tradable quotas would give absolute gains to the DCs (Bohm, 1994b), (Larsen and Shah, 1994). A global regime of tradable quotas will be equal to the (a,a) regime in figure 2.3.1 because DCs would be committed by the allocated emission quotas.

In the remaining of the paper the UNFCCC situation illustrated by the shaded area in figure 2.3.1 will be referred to as the *Greenhouse paradox*, because of the seemingly paradox that ICs accept to abate, and the DCs reject moving to (a,a), even if this could give them absolute gains. In other words there is a conflict between conventional, economic rational free rider analysis and the fact that most international conventions presume the PPP, which is not based on equity considerations.

## 2 Theoretic explanations.

This section analyse the Greenhouse Paradox defined above. It is analysed whether the Greenhouse Paradox can be explained by one of the two well known games, the Prisoners Dilemma and the Hawk-Dove games. Section 3.1 analyses the Prisoners Dilemma and section 3.2 the Hawk-Dove game.

### 3.1 Free riding and the Prisoners Dilemma (PD) - considerations on moral and asymmetry.

Because global warming is connected to the global accumulation of greenhouse gases in the atmosphere, an optimal solution will demand that each country undertakes abatement until its marginal abatement cost equals the sum of global marginal environmental costs as shown by (**) section 1. Because all elements in the transport matrix equals 1 in the GHG case, the result is equalisation of marginal abatement costs among countries;

$$(3.1.1)\ f_{1e}(k_1,l_1,e_1) = ,\ldots, = f_{ie}(k_i,l_i,e_i) = ,\ldots, = f_{ne}(k_n,l_n,e_n) = \sum_j \left(\frac{-u_{jz}}{u_{jc}}\right)$$

If a country decides to free ride, it is only concerned about individual optimality and not about world optimality, therefore it chooses either; to equalise marginal cost to its own marginal damage or not to abate at all. With respect to global warming there is a huge possibility that free riding countries will choose not to abate at all because the main environmental damages incur in the future. This means that abatement policies might be overshadowed by more short run policies.

The PD game is shown in figure 3.1.1.

**Figure 3.1.1: the prisoners dilemma**

| | | B (a) | B (p) |
|---|---|---|---|
| A | (a) | 3 , 3 | 1 , 4 |
| A | (p) | 4 , 1 | 2 , 2 |

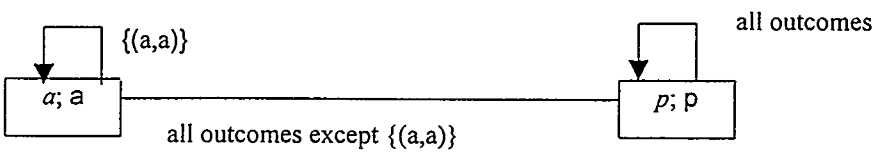
The payoffs in figure 3.1.1 are symmetric. The left hand payoff belongs to country A and the right hand payoff belongs to country B. Now each country will try to maximise its own payoff, given the strategy of the other country. In this way country A's best reaction, if country B chooses abatement (a), is to choose pollute (p) and get payoff 4 instead of 3. If country B chooses pollute (p), it will still be optimal for country A to choose pollute (p) and get 2 instead of 1. Hence, pollute is dominant strategy for country A and because of symmetry also for country B. This means that (p, p) is an equilibrium – formally known as the Nash equilibrium – because no country can be better off given the other country's strategy.

However, if the two countries could agree on choosing abatement and also be sure that none of them will defect, then both will get an even higher payoff (3 instead of 2). Moving from (p,p) to (a,a) is therefore Pareto improving. The problem is that (a,a) is not stable because the incentives to defect from such an agreement is very large. Both countries would get the largest payoff by defecting and joining the benefits from the other country's abatement, while it itself pollute – i.e. by free riding (a pay-off of 4 instead of 3). In a one shot game the Nash equilibrium will, as described above, be (p, p) while the UNFCCC equilibrium according to the greenhouse paradox in figure 2.3.1 is (a,p). This game cannot explain the free riding situation in the UNFCCC as defined in section 2.

There is however one important discussion that can be extracted from the PD game - namely the discussion of free rider deterrence. This discussion will shortly be introduced before moving to the inclusion of asymmetries in the PD.

*Trigger strategies or binding commitments?*
If allowed for repeated games it might be possible to sustain the pareto optimal outcome (a,a). This could be done by using the so-called 'grim strategy' illustrated below (Osborne & Rubinstein 1996; 141).

**Figure 3.1.2: 'the grim strategy'.**




In this strategy the (a,a) situation can be sustained because (p,p) will be played in all following periods if one of the players defect from the abatement strategy. Hence only if the benefit from defecting in one period exceeds the loss from playing (p,p) ever after it will be optimal to defect from the abatement agreement. Other strategies where punishment force the players to stick to the (a,a) agreement or legally binding commitments may also make the agreement stable.

The grim 'strategy' is a so-called trigger strategy and the literature on International Environmental Agreements (IEA) has a debate over whether trigger strategies or binding commitments are the most appropriate mechanism to deter free riding. The debate will shortly be summarised in the following. Barrett (1994a) uses the trigger approach because he does not believe that commitments are possible in the international society. He argues, that in every international agreement or convention on the environment, there is an article or paragraph stating the possibility that a country is allowed to leave the agreement. Therefore commitments are never more binding than, if a country wishes to pull out, it can do so[14].

Barrett (1992; 83-86) argues that commitments will hardly be credible because no legal authority exists to make sure that sovereign states stick to their commitments and because commitment will seldom be individually rational. To keep countries from free riding, the agreement has instead to be made selfenforcing (ibid.; 86 and Barrett 1994a). This can be done through a reward/punishment strategy as follows: '*When a country joins the international agrement, the other signatories increase their abatement levels, and hence reward the country for acceding to the agreement; when a country withdraws , the remaining signatories reduce their abatement levels, and hence punish the country for withdrawing from the agreement.* ' (ibid.; 1).

This trigger strategy involves use of abatement and pollution measures as reward and punishment instruments, but although it might be a credible way to make a coalition self-enforcing, abatement measures might not be persuasive enough. The reason is that the environmental damage is expected to incur in the future and that more short run perspectives often motivate governments. Most analyses of self-enforcing agreements (including Barrett's own) also show that stable coalitions will only contain a small number of countries (less than 4) [15]. The intuitive explanation for the low participation is simple; as the size of the coalition increases the gains from free riding increases - hence only small coalitions with small free rider gains can 'survive'.

Carraro, C. and D. Siniscalco (1993) challenges the above 'trigger-view' by arguing that using abatement/pollution as reward/punishment is not very advantageous. Most environmental agreements can on the contrary be characterised by '*co-operative behaviour among the individual countries involved; they usually have only a sub-group of the negotiating countries as signatories (partial co-operation); and they tend to use various forms of transfers, typically to the developing countries, as a key instrument for increasing the number of signatories.*'(ibid.; 310). Instead of trigger strategies, transfers are argued to increase participation, reduce free riding and keep coalitions stable. Their analyses show that, only together with binding commitments transfers are able to lead to co-operation. With binding commitments it is possible to sustain co-operation by all countries.

To sum up on the above., It is possible to move from the Nash equilibrium (p,p) in the PD to a pareto improving situation (a,a), if trigger strategies or binding commitments are used. The 'equilibrium' in the greenhouse paradox is (p,a) and moving to (a,a) is not expected (by the DCs themselves) to be pareto improving. From this it appears that the PD cannot explain ICs and DCs behaviour in the climate convention.

[14] On a PhD seminar in September 1998, arranged by the Danish network of environmental economists, Barrett himself stated this view several times.

[15] See Barrett 1992a, 1994a, 1995 and Carraro & Siniscalco 1993.

Remember however that the PD is a symmetric game. Below asymmetries are incorporated.

*Incorporating asymmetries - the upstream downstream scenario.*
The payoffs inserted in figure 3.1.1 are results of underlying payoff functions consisting of parameters affected by the abatement policies. If we look more closely at country *i*'s payoff function, for example the one given below, we can see that symmetry involves identical production functions, cost functions and benefit functions[16].

$$(3.1.1) \qquad P_i(a_i, A) = B_i(A) - (Y_i(a_i) + C_i(a_i), \quad i=\text{IC, DC}$$

$B_i(A)$ is country *i*'s benefit from abatement (avoiding environmental damages). This factor is effected by the global abatement level $A$, equal to $a_{DC} + a_{IC}$. $Y_i(a_i)$ is country *i's* decrease in production as a consequence of abatement and finally $C_i(a_i)$ is country *i's* abatement costs.

Notice that $a_i = 0$ describe the situation where country *i* plays pollute. Country *i's* payoff in this situation is equal to the benefit obtained from other countries abatement efforts.

The following asymmetries can for various reasons be expected between ICs and DCs;

$$(3.1.2) \qquad \begin{aligned} &B_{DC}(A) > B_{IC}(A) \\ &Y_{DC}(a_i) > Y_{IC}(a_i) \\ &C_{DC}(a_i) < C_{IC}(a_i) \end{aligned}$$

First of all the benefits from abatement can be expected to be largest in the DCs. This is, as explained in the introduction, partly due to the DCs low adaptation capacity. As an example both Bangladesh and the Netherlands have low lying coastal regions, but while the Netherlands can be expected to have resources to prevent damages from rising sea level, Bangladesh might not. Another reason is that many DCs are extremely dependent on the agricultural sector and this sector is supposed to be the one most hurt by global warming. Second, the DCs must be expected to suffer relatively more from a loss in production because their level of production is relatively low. And thirdly, the abatement costs are expected to be lower in DCs for example due to inefficient energy supplies and energy use.

These asymmetries makes it possible to define the DCs as the victims of the climate problem. Adding the responsibility pattern from section 2 the ICs can be thought of as causing the climate problem. A situation like this is often analysed in the so-called up stream down stream scenario (Mäler 1992). In this scenario, if a polluting country has low environmental damages, it will be characterised as an upstream country, referring to a country that is located at a place where its pollution flows downstream, and thereby does not affect itself. A country with high damage would be characterised as

[16] See Dasgupta (1982) for a similar analysis in an dynamic context with an infinite time horizon.

a downstream country referring to a country located where the emission from the upstream country accumulates. On this background the DC may be downstream- and the IC upstream countries with respect to emission of GHGs.

Assume a situation where the upstream country (ICs) emits $E^0$. The abatement cost of reducing emissions from $E^0$ to $E^*$ equal $c = C(R)$. And $R = E^0 - E^*$ is the emission reduction (abatement). Assume the extreme situation that this country has no damage from its emission, whereas the downstream country (DCs) has damages defined by $D = D(E)$. The downstream country's benefits from emission reductions can be defined as $B(R) = D(E^0) - D(E^0 - R)$ (ibid. ;412). In this situation the downstream country will have an interest in persuading the upstream country to undertake abatement and may even be willing to pay the upstream for abating as long as the sidepayment, call it $S$, is smaller than $B(R)$. There are no economic interest for the upstream country to undertake abatement and it would have strong incentives to "free ride". As a consequence the pollution problem can only be solved by payments from the downstream to the upstream country.

If the two countries negotiate on $R$ and $S$ it is possible that they will reach and agreement leaving them the following payoff (ibid.; 412):

$$\begin{aligned} &P(upstream) = S - C(R) \\ (3.1.3) \qquad & \\ &P(downstream) = B(R) - S \end{aligned}$$

This example indicates the opposite of the polluter pays principle - the victim pays principle (VPP). This principle is based on economic rationality because it is economically rational for the downstream country to pay[17]. When the downstream country is identical to the DCs, as it is conserning global warming, the payment $S$ may however be a threat to the development process in these countries.

Mäler (ibid.; 412-413) refers to Coase's theorem on property rights and argues that if the upstream country has a right to pollute (property rights on the atmosphere), then the VPP will be a result of negotiations, while the PPP will incur if the downstream country has a right to clean air. However there is no property rights defined for the atmosphere, and the Coase theorem therefore does not hold with respec to GHG concentration. The main problem with the adoption of the PPP in the climate convention is that although this principle is appealing on moral and political grounds, the VPP is more in line with economic rationality, which is often the basic incentives in international negotiations.

The adoption of the VPP in cases where no property rights are defined are underlined in an analysis of the acid rain problem by Kaitala, V. and M. Pohjola (1991). Their analysis concludes that the victim pays principle would be an optimal solution in a bilateral agreement on $SO_2$ reductions between Finland and the Soviet Union.

In a later paper Kaitala, V. and M. Pohjola (1997) uses the upstream downstream approach in an analysis of the global warming problem in a differential game set-up. They argue that there is a 'winning' part (upstream) with small damages from global

[17] Notice that the economic rationality in the VPP makes it necessary that environmental damage is valuable and incorporated by the decisions makers in environmental negotiations.

warming and a 'loosing' part (downstream) with large damages from global warming. The VPP is also suggested as solution to this problem by assuming that the loosing part is putting pressure on reaching an agreement and eventually use sidepayments to persuade the winning part to take action. As a consequence Kaitala and Pohjola analysis implicitly assumes that the DCs are willing to pay the ICs to cut GHG emissions, which is completely the reverse of the suggestions in the Climate Convention text.

The core of this problem is that in the absence of property rights on the atmosphere the PPP is based on moral concerns, while the VPP is based on economic rational concerns. Because nations incentives are basically bound in economic interests the VPP can be expected to be the most obvious outcome of international environmental negotiation. Even though the text in the Climate Convention presume the PPP there is a great chance that negotiations will lead to the VPP being adopted.

We can illustrate the asymmetric PD by letting player A be DCs and player B be ICs. Because DCs are relatively vulnerable to global warming 1 unit of payoff is subtracted every time (p) is played. This means that in (a,p) DCs payoff is now 0 instead of 1, in (p,p) the payoff is 0 instead of 2 and in (p,a) the payoff is 3 instead of 4. DCs relatively low abatement costs would tend to increase their payoff relative to the ICs in situations where they play abate, but this effect is neutralised because they also are relatively more hurt by the loss from foregone production. The asymmetric PD are shown in figure 3.3.1 below.

Playing (p) is still the dominant strategy for ICs, but now the DCs are totally indifferent between playing (a) or (p). This can be explained be the fact that they are both hurt by undertaking abatement and by not doing so - the latter however demands that damages are valuable and incorporated in decision making. The outcome is two possible Nash equilibria where one of them (a,p) is pareto preferred to the other (p,p). Figure 3.1.3 show that DCs will gain 3 unit payoff if they move to the (a,a) equilibrium while IC will loose 1. If however DCs transfer for example 1½ of the 3 units payoff to the ICs (indicating the VPP), then moving to (a,a) would be pareto improving. This situation will not be stable because DCs will have incentives to defect.

**Figure 3.1.3: the asymmetric PD**

| | | ICs a | ICs p |
|---|---|---|---|
| DCs | a | 3 , 3 | 0 , 4 |
| | p | 3 , 1 | 0 , 2 |

To summarise we can characterise the two groups of countries as shown in table 3.1.1.

**Table 3.1.1 free rider incentives and asymmetries.**

| | Abatements cost | GDP level | Environmental damage by climate change | Emission level | Willingness to take action |
|---|---|---|---|---|---|
| IC | High* | High | Low* | High | High |
| DC | Low | Low* | High | Low* | Low* |

Note: * refers to the presence of free rider incentive

These characteristics, together with the above analysis, give the following free rider incentives. Column 1 shows that IC, ceteris paribus, has an incentive to free ride when world cost effectiveness is in focus because more abatement could be undertaken in the DCs for a given amount of resources. Column 2 show that DCs would have an incentive not to participate because the production foregone when undertaking abatement is relatively large. Column 3 indicates that ICs can be characterised as upstream- and DCs as downstream countries. Hence column 3 indicates that ICs might have incentives to free ride. Together column 1-3 might give the situation illustrated in figure 3.1.3. The two last column's gives two free rider incentives to the DCs because of relatively low responsibility (column 4) and low political willingness (column 5). These two columns are based on moral concerns and not on economic rationality. These characteristics have not been incorporated in the PD.

### 3.2 Free riding and the Hawk-Dove game - consideration of a sequential bargaining structure.

Another game can be used to describe the UNFCCC situation - this is the Hawk-Dove game.[18] This game originally described two animals fighting over some prey. Each animal can behave like a dove or a hawk. The dove behaviour can be characterised as the abatement behaviour in the UNFCCC game, while the hawk behaviour can be characterised as the pollute behaviour.

The best outcome to each of the players is the situation, where he or she pollutes (play hawk), while the other player abates (play dove). So far the game is equal to the PD. But where the worst outcome for each player in the PD game is the situation where the other pollutes and s/he abates, the worst situation in the Hawk-Dove game is that both players pollute (play hawk). The game is illustrated in figure 3.2.1 below.

[18] See e.g. Carraro and Siniscalco 1993.

**Figure 3.2.1 The hawk-dove game**

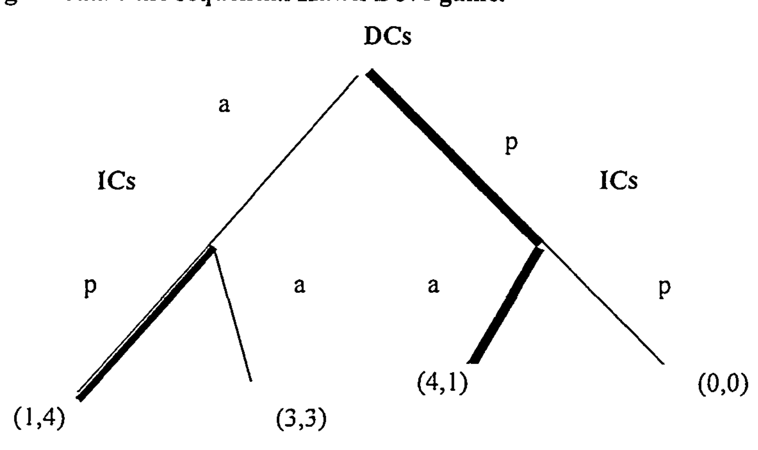
| | | ICs: a | ICs: p |
|---|---|---|---|
| DCs | a | 3,3 | 1,4 |
| | p | 4,1 | 0,0 |

There are two Nash equilibria (a,p) and (p,a) in the game, and (a,a) is not a pareto improving option.

Which of these two possible Nash equilibria will result? If applied to the UNFCCC game, it might be the case that the responsibility pattern, as explained above, will institutionalise a norm that favours (p,a) in relation to (a,p). Hoel and Schneider (1997) use this type of norms and conventions in an analysis of side payments and participation in International Environmental Agreements (IEA). They conclude that given the possibility that non-participating countries receive side payments, they might have an incentive to stay out, because they know that they then will be offered side payments to participate later.

Just like the introduction of norms and conventions might lead to favouring one of the Nash equilibria, a dynamic framework, for example whith a sequential structure, may lead to the (p,a) solution. Assume that there are 2 stages in the game, that the DCs in the first stage can choose between abate (a) and pollute (p), and that ICs afterwards can choose between (a) and (p). This is illustrated in figure 3.2.2 below.

**Figure 3.2.2: the sequential Hawk-Dove game.**



The game can be solved by backwards induction, and we start by defining the ICs' behaviour in the second stage. In the subgame where DCs have chosen (p) ICs will prefer to play (a), because it gives payoff 1 instead of 0. In the other subgame where DCs have played (a) ICs will prefer to play (p) instead of (a) because this gives payoff 4 instead of 3. In stage 1 DCs know ICs preferences in stage 2, and they therefore foresee that playing (p) in stage one will give them the highest payoff (4 instead of 1).

A subgame perfect equilibrium is thus an equilibrium that survives when each player is required to reassess his plans as the game proceeds[19]. DCs, actually gains from being the first to move. This situation can explain how to choose among the two Nash equilibria in the Hawk-Dove game. If the Hawk-Dove game is supposed to explain international environmental bargaining then the fact that DCs, due to the awareness of differentiated responsibilities, are allowed to move first this can explain the outcome of the UNFCCC negotiations (the greenhouse paradox).

Barrett (1998) uses a similar game theoretic set-up to explain the effect of transfers on the coalition formation in the case of the Montreal Protocol. He infers from the low development level of the DCs that they are pre-committed to non participation. In this way free riding can be deterred because of the presence of pre-commitment. As explained in section 2.2, Carraro assumes that commitments are due to political willingness while Barrett assumes that commitments are due to asymmetries.

Starting from the Hawk-Dove game, the Greenhouse paradox can be a Nash equilibrium either if norms and conventions favour the DCs or if a sequential bargain structure is added, such as to allow DCs to initiate negotiations.

## Conclusions.

This paper has analysed the economic and moral rationality behind the different positions of the Developing and Industrialised Countries with respect to the Climate Convention. The upstream - downstream anlysis, and the Victim Pays Principle do not explain the different positions. The Polluter Pays Principle and the Hawk-Dove game can explain the different positions. The Polluter Pays Principle may be based on moral rather than economic rationality.

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[19] Osborne and Rubinstein, 1996; 89.

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# Working Paper

# Will CDM be an Obstacle to Later Commitment by Non Annex B Countries to Fixed Reduction Targets

**Abstract:** *The Clean Development Mechanism (CDM) defined by the Kyoto Protocol, article 12, gives Annex B countries a possibility to substitute part of their national emission reduction obligations for abatement projects in the non committed countries: The industrialised Annex B countries finance abatement projects in the developing, Non Annex B, countries and will be credited the emission reduction on their own emission budget.*
*The main purpose of the CDM is to undertake the Annex B countries abatement in a cost efficient way. But the CDM may also be seen as an initialisation of the developing countries (DCs) participation in policies to reduce clobal warming.*
*In the litterature, for example Bohm (1994b), it has been argued that CDM is an obstacle for Non Annex B countries to later commitment to fixed reduction targets – and thereby an obstacle to the development of a broad system of Tradable Permits (TP). The present paper analyses the formalised arguments in Bohm (1994b) and shows how the arguments depend on the specific assumptions made. The paper widens Bohms analysis with leakage effects and other more dynamic aspects of CDM which support the conclusion that initial CDM will not necessarily be an obstacle for the non annex B countries to later commitment to fixed reduction targets.*

## Introduction.

Bohm (Bohm, 1994a, 1994b) comes to the conclusion that JI will reduce Developing Countries' (DCs') incentives to join a system of tradable permits, by reducing what he, in his analysis, calls tradability gains. Also Hoel () puts this argument forward. The present paper analyses the formalised arguments in Bohm (1994b) and shows how the arguments depend on the specific assumptions made. The paper widens Bohms analysis with leakage effects and other more dynamic aspects of CDM, which support the conclusion that initial CDM will not necessarily be an obstacle for the non annex B countries to later commitment to fixed reduction targets.

Section 1 presents Bohm's analysis and discuses his assumptions. Section 2 analyse tradability gains in a more general framework. Section 3 concludes.

## 1. Bohm's analysis of "tradability gains"

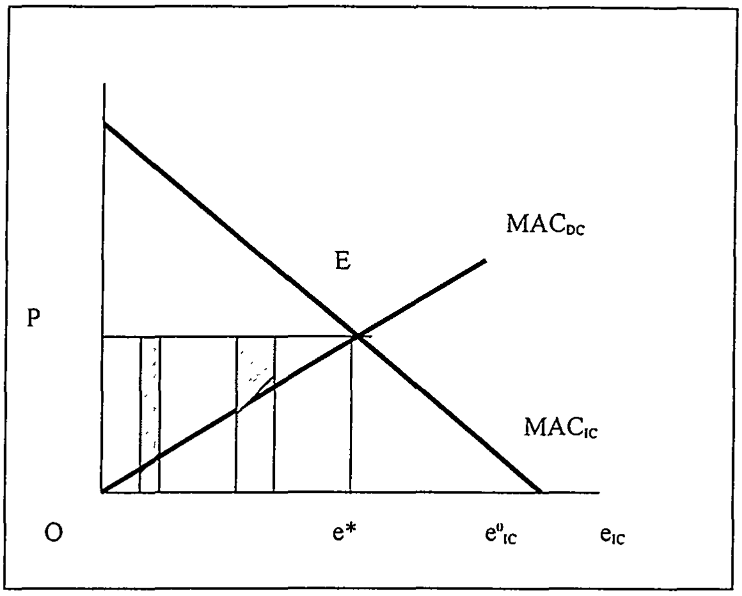
Because the global warming problem is a long run problem it is important to analyse the long run consequences of policy instruments. JI is primary an instrument to improve cost efficiency. But how does JI affect the Developing Countries incentives to commit to fixed reduction targets?. The developing countries – which are identical to the non Annex B countries – may be said to free ride against the Kyoto Protocol, because the non Annex B countries are not committed to reduce emissions, but enjoy the emission reductions of the committed Annex B countries. Will JI enhance the DCs' free rider incentives and make the DCs' future commitment more unlikely? Or will the oppersite be true; that JI will DCs' future commitment to fixed reduction targets more likely. Will JI between annex B (ICs) and non-annex B countries (DCs) affect the DCs' free rider incentives?

On the one hand it could be that because JI in many ways are identical to a TQ regime then it could develop into a TQ regime[1]. On the other hand DCs could argue that if they participate in JI the additional gains from going to a more comprehensive TQ regime would diminish. This chapter departs from one of the most quoted analysis of the question: Peter Bohm's 1994 paper to the IPCC WG III (Bohm 1994a) and his later paper on tradability gains (Bohm, P., 1994b).

Bohm (1994a) assumes that a tradable quota (TQ) regime including the DCs will be established and ask if JI will reduce DCs' incentives to join this regime. It is assumed that quota allocations to DCs in the TQ regime are based on baseline[2] emission so that abatement from initial JI projects will not be undermined[3]. Bohm then uses a figure equal to figure 1 below to argue that JI will reduce the DCs' incentives to join a TQ regime.

The figure shows that the DCs' gains from trade in the absence of JI is equal to the triangle OEP. This triangle equals the export revenue (quota unit price times quota export) OPEe* minus abatement costs OEe*. If, however, JI is implemented prior to the TQ regime and e.g. the two projects marked by the shaded areas are carried out in JI operations, then the DCs' gains from entering the TQ regime will be lowered by the amount of the shaded areas. This is because the DCs are now unable to sell these 'projects' at the TQ price. Hence Bohm concludes that: *'If the DCs' willingness to join the TQ treaty depends on the expected benefits from joining, the DC may now decline to co-operate'* (Bohm, P., 1994a; 13).

**Figure 1: Tradability gains and Joint Implementation.**




Source: Bohm 1994a; figure 4

His formulation indicates that it is *possible* that JI will make DCs to sustain their free riding position. In a later paper, however, Bohm uses the conclusion to say that JI prior to a TQ regime *will* reduce the DCs' incentives to join a TQ regime and show instead that DCs' gains from joining the TQ regime, in the first place, will be positive (Bohm, P., 1994b; 195-196).

This paper will re-investigate the ambiguity actually found in the conclusion in Bohm's first paper. First we argue that the question whether JI reduces DCs' incentives or not is indeed ambiguous. This is done in section 2. Second we discuss the assumptions of allocation based on baselines and the possibility that it may not be a realistic allocation rule for the UNFCCC case. This is done in section 3. Finally, in section 2, we set up Bohm's model in a more general framework and show that JIs' effect on tradability gains may be changed if this allocation principle is changed. we find that the effect depends on the relationships between the countries MAC curves and on the relationship between baseline emission and quota allocation. Initially we will summarise Bohm's analysis of tradability gains (Bohm, P., 1994b).

*Tradability gains.*

DCs are provided with an initial quota allocation equal to their baseline so that reductions from previous JI-projects will not be undermined. ICs are committed to reductions by a quota less than baseline. Using Bohm's notation $E_i^0$ equals country $i$'s baseline emission ($i$=I, D where I refers to IC and D refers to DC), $E_i^A$ equals country $i$'s initial emission allocation and $E_i^*$ equals country $i$'s emission after trade. This means that;

$$E_D^0 = E_D^A > E_D^* \text{ and}$$

(1.1)

$$E_I^0 > E_I^* > E_I^A$$

Because of the absence of abatement requirements on the DCs, all abatement undertaken are exported.

While DCs' tradability gains (OEP in figure 3.1.1) can be defined as quota sales minus abatement costs they are expressed by:

(1.2) $G_D = p\,(E_D^0 - E_D^*) - \frac{1}{2}c_D(E_D^0 - E_D^*)^2$

where $p$ is the quota-unit price and $c_D$ is the slope of the DCs marginal abatement cost curve. The second part on the right hand side is thus the total abatement cost function. A word should be added to its specification.

This specification is often used (besides Bohm see e.g. also Carraro, C., 1993, 1997a, 1997b and Barrett, S. 1994a), but it has several implications that needs to be addressed. First of all, the form of the total abatement function implies rising marginal abatement costs $(c_D(E_D^0 - E_D^*))$, and second of all it implies that leakage is neglected. The first implication is rather conventional and does not cause any inconvenience. But because the cost function is static, it cannot capture the fact that MACs increase over time because of the historic accumulation of abatement[4]. Therefore it relates more to a flow pollutant than to a stock pollutant such as GHGs.

Opposite Bohm who agues for the absence of leakage by assuming that '*carbon tariffs or similar actions are taken by signatories to prevent any significant carbon leakage through trade*' (Bohm, P., 1994b; 198), we will argue in section 3.2 that absence of leakage actually should be identified with a JI regime. The no-leakage assumption is furthermore rather determinative for the conclusions.

The quota unit price and the level of trade are determined by the equalisation of MACs between ICs and DCs and the limitation of the total quota allocation:

(1.3) $p = c_d(E_D^0 - E_D^*) = c_I(E_I^0 - E_I^*) = c_D(E_I^* - E_I^A)$ given,

(1.4) $E_D^* + E_I^* = E^T$

where $E^T$ is the total quota allocations. The last equalisation in equation (1.3) rests on the assumption that DCs quota allocation equals their baseline so that total abatement equals its exports and thereby also the ICs imports.

Bohm now inserts the last expression of $p$ in (1.2) and gets:

(1.5) $G_D = \frac{1}{2}c_D(E_I^* - E_I^A)^2 > 0$

Thus, given (1.1) the DCs tradability gains are positive in the analysed situation. Furthermore, it shows that the gains are rising in $c_D$ and if we use equation (1.1) we can rewrite (1.5):

(1.5') $G_D = \frac{1}{2}c_I(E_I^0 - E_I^*)^2 > 0$

and see that $G_D$ is also rising in $c_I$.

Notice that some argues, that because JI exhausts the cheapest abatement projects in DCs, their MACs will rise and as a consequence of this the cost for future commitments will rise. Here Bohm's result actually shows the opposite - namely that tradability gains increase as MACs increases. This could be explained by the fact that no abatement commitments are laid on the DCs' shoulders as long as they are given allocations equal to baseline and while the rise in MACs increases the quota unit price their gains will increase.

*JI and DCs incentives to join a TQ regime.*
From the summary of Bohm's analysis it could be concluded that if allocations are based on baseline emissions then i) JI will reduce DCs gains from joining a TQ regime and hence it could involve free riding to be sustained ii) if DCs joined a TQ regime in the first place their gains would be positive and positive related to the slope of both ICs and DCs MAC curve.

If this is the correct description of the connection between JI and free rider incentives, then the cost efficiency gained from JI is not much worth in a long run perspective. Bohm's conclusions are based on; figure 3.1.1 and the assumption of baseline allocation (i.e. $E_D^0 = E_D^A$). We will assess these in turn.

*Comments on figure 1.*
Now what can be said about figure 1 ? Well, first of all it must be noticed that the DCs still have gains from entering the TQ regime even though they are reduced because of the JI projects - they still have an incentive to join the TQ regime. If the DCs could be sure that a TQ regime would be implemented in the future, then it would ceteris paribus not be rational for the DCs to engage in JI. But if the DCs are uncertain about the establishment of TQ, then the scenario could be more sequential. It could then be rational to engage in JI if this gives positive gains, and then again later if joining a TQ regime has positive gains, it would be rational at that time to join this regime.

The loss from initial JI illustrated by the shaded areas might furthermore not be as large as postulated. It is not given that DCs will only receive the MAC in exchange for the JI projects and hence the loss might not be so large. Because of cost efficiency the ICs total abatement costs are lower compared to a situation where they would have to undertake all of the abatement 'unilaterally'. Therefore the DCs might be able to 'sell' the JI projects at a price higher than the DCs' MAC as long as the ICs will experience some degree of cost efficiency.

There could also be some additional gains from JI following from the technology transfers that are not shown in the figure. These gains could be an incentive for the DCs to join JI projects, even though they are aware, that joining JI now may reduce their gains from joining a TQ regime later. In fact, a situation where the DCs are indifferent between having a JI regime prior to a TQ regime and not having JI prior to a TQ regime could arise. If the DCs could succeed in obtaining a price for the JI projects that is larger than MAC, the loss from JI is maybe only half of the shaded area in figure 3.1.1. If the additional gains from technology transfers at least equals the rest of the shaded areas, the DCs' gains would not be affected of the initial JI regime.

Another situation that was shortly noted above is neglected in Bohm's analysis. If the framework where more sequential, 2 periods could arise. In period 1 IC had committed to emission reductions that either could be undertaken through JI or unilaterally. In period 2 new commitments will be made and these are allowed to be traded in a global TQ regime. Then if the commitments in period 1 could be undertaken through JI, then ICs might be willing to commit to larger reductions in period 2. This could be strengthened if JI reduces leakage because ICs abatement effort would then be more effective and hence they would be more willing to accept more ambitious reduction targets. This could result in more trade and hence more gains to the DCs. Part III will take up this perspective by modelling the JI/TQ relationship in a sequential bargaining model.

The problem, claimed by Bohm, that net abatement is reduced when allocations are not based on baselines and JI is implemented prior to the TQ regime, may be exaggerated. This is because JI could be supposed to reduce leakage and hence improve the effectiveness of ICs' abatement. The rise in ICs' net abatement due to reduced leakage could outnumber the loss in emission due to JI followed by allocations not based on baseline. But can we be sure that leakage is reduced because of JI? Below we try to find arguments for this.

The free rider problem discussed so far is connected to the social inoptimality that arises when not all countries participate. Free riding means that world marginal benefits are greater than marginal costs, with a too low abatement level as a consequence. Another problem which we already has referred to several times has yet to be assessed. This problem is in the literature described as 'leakage' and arises when increasing emission in the free riding countries offsets abatement measures undertaken by co-operating countries.

Leakage arises mainly through trade effects and therefore trade restrictions are often suggested as a way to reduce leakage. This kind of policy is, however, not always fair. If for example the non-participating countries free ride because of low economic development, the economic loss from undertaking abatement could be threatening their ability to fulfil basic human needs. Trade restrictions could be holding these countries trapped in poverty, and this is not in the interest of any of the countries.

If trade restrictions are called the 'stock' policy, JI could in this connection be thought of as a possible so-called 'carrot' policy to reduce leakage (See Barrett, S., 1994b; 25 and Barrett, S., 1995; 18). This mechanism does not reduce the leakage effect by punishing the free riders through trade restrictions, but by making them join abatement implementation by transferring new technology. There is four obvious ways in which abatement undertaken by a group of countries can be undermined by increased emission in free riding countries. We will try to assess how JI can reduce these effects.

First of all abatement measures raise the cost for the participating countries' industry and hence comparative advantages shift to non-participating countries.

This means that when participating countries reduce their fuel intensive production because of rising cost, non participating countries will raise their fuel intensive production and hence their emission. This effect, however, depends on the trade volume between participating and non-participating countries and on the degree of substitution between IC and DC tradable's. What JI now does to this leakage effect is that it tends to equalise the marginal abatement cost and hence reduce the level of the shift in comparative advantage. Non-participating countries' emission levels are therefore not affected by participating countries' abatement measures.

The second channel through which leakage is working is also connected to trade effects. It could be expected that abatement undertaken by annex I countries would make the world demand for fossil fuels to fall and hence reduce the price on fossil fuels. This would make the non annex countries increase their use of fossil fuels and hence undermine the abatement undertaken. When transferring new technology, with less fossil fuel consumption, to the non-annex countries through JI projects, their demand for fossil fuels would fall and thereby lower the described leakage effect.

Thirdly if we assume that free riding countries only undertake abatement such as to equalise their marginal costs to their own marginal benefits - that is $MAC_D = MB_D$ - we can expect that they will reduce this abatement when participating countries increase their abatement measures. If we assume that MB positive but decreasing when abatement increases, this leakage effect is effectuated through the reduction in marginal benefit when abatement rises. It is not obvious how JI will affect this mechanism, but with the free riding incentives in focus here this mechanism might not be that substantial. Both because the free riding countries are hardly undertaking abatement at all and because abatement benefits are not very likely to be used as policy indicator.

Finally it can be expected that IC industries, that are subject to environmental regulation (e.g. $CO_2$ taxes), will move their 'dirty industries' to DCs with no regulation. The empirical evidence on this issue show that environmental regulation is a less important factor when industries choose location (Jaffe et. al 1995). It is not obvious how (if at all) JI will affect this situation.

*Comments on the assumption of quota allocations*

When Bohm concludes that JI will reduce DCs' incentives to join a TQ regime, it is based on the assumption that DCs are given quotas equal to their baseline emissions. There is, however, no guarantee that this allocation principle will be used in a TQ regime in the UNFCCC case. What are the alternative allocation principles and which will most likely be used in the UNFCCC case? The purpose of this section is to answer this question.

Allocations involve welfare changes and might therefore affect the countries' incentives to join a TQ regime. Barrett expresses the importance of initial allocations by; " *the initial allocation of permits creates wealth. The issue is not purely distributive, for the initial allocation will determine which countries sign an international agreement* " (Barrett, S., 1991; 90).

Thus when analysing free rider incentives, in relation to a TQ regime, a discussion on allocation principles is extremely relevant. Bohm only takes the view as to which allocation principle is the most optimal according to environmental goals, but in the negotiations bargaining will also be on the distributive and participation perspectives.

Larsen and Shah show in an interesting study how different allocation principle might change different countries' (regions) gains from entering a TQ regime. It is supposed that emission should be reduced to 1987 level in year 2000. Their analysis shows that allocation principles do change the post trading costs and thereby also the participation incentives. Furthermore they show some interesting results in connection to the questions raised in this paper (Larsen, B. and A. Shah, 1994).

In the scenario Larsen and Shah investigate the allocation principle based on population involves DCs to revieve quotas that are larger than their baseline. Their analysis shows that if allocations are based on countries share of world population[5], then decreasing baseline emission per capita will increase the benefits from quota tradability. This conclusion is interesting because it indicates that JI through decreased baseline could increase DCs' benefits. Later we will show that if Bohm's analysis of tradability gains are set up in a more general framework, then the same conclusion regarding JI can be reached; if MACs are uniform and allocations are based on population, then reduced baseline (JI) will increase DCs' gains.
Larsen and Shah further show, in empirical simulations, that if allocations are based on population then all DCs will gain from quota trade. OECD countries will have lower costs than if they were to undertake all abatement 'unilaterally', but middle income countries such as the economies in transition may have relatively high costs. The last may as a consequence decline to participate (ibid.; 846). Remember from section 2 in chapter 1 that the DCs in general and India in particular argue for a population based responsibility perspective. If forced to negotiate emission allocation, India's position would obviously be to argue for population based allocations.

Finally they show that if allocation is formed so that non-OECD countries are fully compensated, then OECD countries still have lower costs than if they were to undertake all the abatement unilaterally and all non-OECD countries and countries in transition have positive gains from trade. Therefore it is concluded that this allocation principle is the most appropriate for inducing all countries to participate (ibid.; 850).

One can think on the allocation debate in another way by looking at the GHG accumulation as a global externality with the characteristics of a public good; no one can be excluded from the damage of the externality. Then by following Coase (1960), if i) property rights are defined and ii) there is a small number of involved parties and iii) no transaction costs, then negotiation and/or trade will secure an optimal use of the externality, no matter how the property rights are distributed[6]. The problem with global warming is, however, the large number of agents involved - all human beings now and in the future. This means that the bargaining process first of all is connected to huge transaction costs and second of all

bargaining among the involved agents is not even possible if one take the intergenerational view on the problem. Baumol and Oates state that the Coase theorem might hold true only for the case where a small number of agents are involved and hence not for the global warming case (Baumol and Oates, 1988; 35). It could though be argued that the distribution of property rights (emission quotas) does matter in the global warming case.
Anyway, Rose and Stevens show that the welfare effects of allowing for quota trade are not effected by the initial distribution of quotas. Their empirical results show that post trading abatement cost for any country will always be the same for a given CO2 reduction target no matter what the initial allocation of permits may be (Rose and Stevens, 1993). The conclusion of their analyses is hence indicating that the Coase Theorem holds in the sense that no matter how quotas are distributed, the outcome will be the same.

In the Kyoto protocol which is a non-tradable quota (NTQ) regime, the quotas are based on base year emissions - 1990 in most cases. The committed Annex I countries are however obligated to reduce emission with a different percentage under 1990 emission level. The EU have for example committed to reduce emissions to 8% *less* than 1990 emission while Australia has committed to reduce emissions to 8% *above* 1990 emission level. This may be called a modified grandfathering principle.

Every signatory has different gains and losses from using exactly this base year and it would be painful to re-negotiate which base year to use. The G-77 and China have posed a list of questions regarding the flexibility mechanisms in the Kyoto protocol. In article 17 on International emission trading, it is asked how the emission rights of developed country parties are to be determined. In a shared answer by a group of the largest ICs including USA, Australia, Japan and Russia but excluding EU it is stated that while the '*assigned amounts in the Kyoto Protocol were negotiated so as to reflect enhanced developed country responsibilities (in that they do not apply to developing countries) and to reflect equity the allocations from which international emission trading among ICs begins are the assigned amounts reflected in the Kyoto Protocol*' (UNFCCC, 1998b; 43-44).

It is therefore likely that quotas in a later TQ regime also would be based on 1990 emission levels. A further advantage with base year allocations compared to baseline allocations, is that it is well known for almost all countries. This cannot be said about baseline emissions, which could be extremely difficult to estimate. Indeed DCs would have an incentive to overestimate their baseline such as to get larger quotas - hence if incomplete information is incorporated, even baseline allocations could lead to ineffective abatement measures.

The allocation principle where quotas are based on historic emissions is discussed in the literature as the grandfathering principle and is stated by Pearce as: "*the only initial allocation that will meet with agreement*" but he further states that: "*The sheer newness of tradable permits on the international scene may in any event militate against them totally. If so, one essential message for international negotiators is that they should 'mimic' as best they can the efficiency of market based approaches*" (Pearce, D., 1990; 385). In this statement a recommendation to

JI might be hidden, while this system in many respects mimic the workings of a TQ regime.

To sum up on the above it can be related to equity concerns. Table 1 lists various equity principles and related allocation rules.

**Table 1: Quota allocations and equity principles.**

| Equity principle | Allocation rule | Relatively largest share to: |
|---|---|---|
| Ability to pay | Allocate by total cost relative to GDP | DC |
| Rawls (maxmin) | Largest quotas to DCs | DC |
| Sovereignty | Current or baseline emission | IC |
| Egalitarian | Population based allocation | DC |
| Polluter pays | Allocation based on the inverse of historic emissions (grandfathering) | DC |
| Consensus | Grandfathering | IC |

Source: discussion above and Rose and Stevens 1993

The table shows that DCs would have relatively high allocations if ability to pay, Rawlsian, egalitarian and polluter pays principles are used. This rests on the fact that even though DCs may have low MACs, their total abatement cost might involve a large share of GDP and hence ability to pay would be low. If Rawls criteria of maximising the benefits of the countries with the lowest total benefits is chosen it would also require relatively large quotas to the DCs. Egalitarianism would view the atmosphere as a global common that every human being should hold an equal property right to use - hence allocations would be based on population which would again result in large quotas to DCs. Finally the polluter pays principle catches the historic responsibility of the ICs and in this way demands large quotas to DCs.

The only equity principle covering baseline allocation is the sovereignty principle, but while it is clear that not all countries can be given allocations equal to baseline because this would involve no abatement to be undertaken, this principle cannot be working alone.

On the background of the above discussion it is our opinion that the most likely allocation rule will be a modification of the grandfathering principle also used in the Kyoto protocol. It may be the case that allocations to the DCs will be equal to a base year emission level (e.g. 1990) while the ICs' allocations then are equal to this base year emission level minus a percentage reduction. Rejecting Bohm's allocation projection also means that we reject his conclusion that JI reduces DCs' incentives to participate in a future TQ. To see this we will set up Bohm's analysis in a more general framework.

## 2. Tradability gains - a more general set-up.

Assume that $E_D^A \neq E_D^0$ and that DCs are assumed to be net exporters of quotas in a TQ regime hence:

$$(2.1)\qquad \begin{aligned} E_D^A &> E_D^* \\ E_I^* &> E_I^A \end{aligned}$$

The tradability analysis is a partial analyse where the ICs need not be modelled. In this way the asymmetries are not very clear, but the assumption that DCs are net exporters implicitly assumes that DCs has the lowest MACs. Later we will assume that ICs prior to the TQ regime have had reduction commitments that could have been undertaken through JI. This incorporates the fact that DCs prior to the TQ regime have been free riders.

By definition exports must equal imports and total emission must be no larger that total quotas allocated, hence the following must hold:

(2.2) $(E_D^A - E_D^*) = (E_I^* - E_I^A)$

(2.3) $E_D^* + E_I^* = E^T$

The DCs tradability gains are still quota sales minus abatement cost:

(2.4) $G_D = p(E_D^A - E^*_D) - \frac{1}{2}c_D(E_D^0 - E_D^*)^2$

Notice that because $E_D^A \neq E_D^0$, the tradability gains can not be written as (1.2). The quota unit price is, however, still found by equalisation of MACs, but the last part of (2.3) no longer holds - that is:

(2.5) $p = c_D(E_D^0 - E_D^*) = c_I(E_I^0 - E_I^*)$

Inserting p in (2.4) no longer helps us to get as simple an expression of tradability gains as (1.5) because DCs' total abatement no longer necessarily equals DCs' total exports or total imports by ICs. Only if DCs are allocated quotas equal to their baseline this will be the case. Inserting $p$ gets:

(2.6) $G_D = c_D(E_D^0 - E_D^*)(E_D^A - E^*_D) - \frac{1}{2}c_D(E_D^0 - E_D^*)^2$

by re-arranging:

(2.6') $G_D = c_D(E_D^0 - E_D^*)*[(E_D^A - \frac{1}{2}(E_D^0 + E_D^*)] > 0$

for $E_D^A > \frac{1}{2}(E_D^0 + E_D^*)$

$E_D^A > \frac{1}{2}(E_D^0 + E_D^*)$ is a sufficient condition for positive tradability gains because the term outside the brackets is positive by definition. [7]

Where Bohm assumes that $E_D^A$ equals $E_D^0$, we will assume that $E_D^A$ is a given constant (e.g. equal to the 1990 emission level) and therefore reductions in baseline will increase the chance that $E_D^A > \frac{1}{2}(E_D^0 + E_D^*)$. But we cannot be sure that decreasing baseline will increase tradability gains because as shown below $dE_D^0/dE_D^* < 1$ - hence the first part of (2.6') ($c_D(E_D^0 - E_D^*)$) will fall when baseline falls. The net effect is therefore ambiguous.

Remember that we are interested in the effect of decreasing baseline because this is an effect of JI. Under Bohms's assumption decreasing baseline will result in decreasing allocation and less gains, but when allocations are given decreased baseline could either increase or decrease gains. If JI reduces leakage, as we assume, DCs' baseline would fall by more than just the abatement undertaken in JI projects, which will strengthen our argument.

In order to assess how JI affects tradability gains, we will calculate the derivative of (2.6') with respect to $E_D^0$ and $c_D$, because JI is causing reductions in $E_D^0$ and higher MACs which can be approximated by higher $c_D$.

If we differentiate (2.6') with respect to $c_D$ we get: $(E_D^0 - E_D^*)*[(E_D^A - ½(E_D^0 + E_D^*)]$ which is positive for $E_D^A > ½(E_D^0 + E_D^*)$. Hence only if allocations secure that DCs are equally well off, an increase in $c_D$ will lead to rising gains. The reason is that the rise in MAC increases the quota unit price and hence exports revenue. In the case where DCs are equally well off, the increase in export revenues are not undermined by abatement costs.

To calculate the derivative, with respect to baseline, some initial calculations are necessary. Using (2.3) and (2.5) DCs emission after trade can be calculated as[8]:

$$(2.7) \quad E_D^* = \frac{c_D E_D^0 + c_I (E^T - E_I^0)}{c_D + c_I}$$

and it shows that $E_D^*$ is a function of $E_D^0$, $E_I^0$, $E^T$, $c_D$ and $c_I$.

From (2.5) we know that the quota unit price $p$ is a function of $E_D^0$ - hence differentiating (2.4) with respect to $E_D^0$ results in:

$$(2.8) \quad \frac{dG_D}{dE_D^0} = \frac{dP}{dE_D^0}(E_D^A - E_D^*) - p(\frac{dE_D^*}{dE_D^0}) - (1 - \frac{dE_D^*}{dE_D^0})(E_D^0 - E_D^*)$$

If JI shall improve tradability gains, this equation has to be less than zero. From (2.5) and (2.7) $dp/dE^0_D$ and $dE^*_D/dE^0_D$ can be calculated:

$$(2.9) \quad \frac{dE_D^*}{dE_D^0} = \frac{c_D}{c_D + c_I} < 1 \text{ to simplify notation } \frac{dE_D^*}{dE_D^0} \equiv \gamma$$

$$(2.10) \quad \frac{dP}{dE_D^0} = c_D(1-\gamma) > 0 \text{ given } \gamma < 1.$$

There are three effects on gains from reduced baseline emission that can be seen from (2.8), (2.9) and (2.10). First (2.9) shows that reductions in baseline emission by 1 unit will reduce actual emission by less than one. This has two consequences: i) total abatement $(E_0 - E^*)$ will decrease and hence reduce total abatement costs, ii) the export level $(E_A - E_0)$ will increase and hence raise revenue from exports. But in (4.4.10) the reduced baseline makes the quota unit price fall and hence pulls in the opposite direction of ii). Obviously then further analyses of the equations are needed to learn more about the sign of (2.8)

Inserting (2.9) and (2.10) in (2.8) determines that the following must hold if (2.8) should be less than zero:

$$(2.11)\quad c_D(1-\gamma)(E_D^A - E_D^*) < ((c_D - 1)\gamma + 1)(E_D^0 - E_D^*)$$

To start with the case where allocations are set equal to 1990 emission level, this case may involve allocation to be less than baseline. Given that allocations are smaller than baseline, we have that $(E_D^0 - E_D^*) > (E_D^A - E_D^*)$ and hence a sufficient condition to satisfy (2.11) is when inserting for $\gamma$:

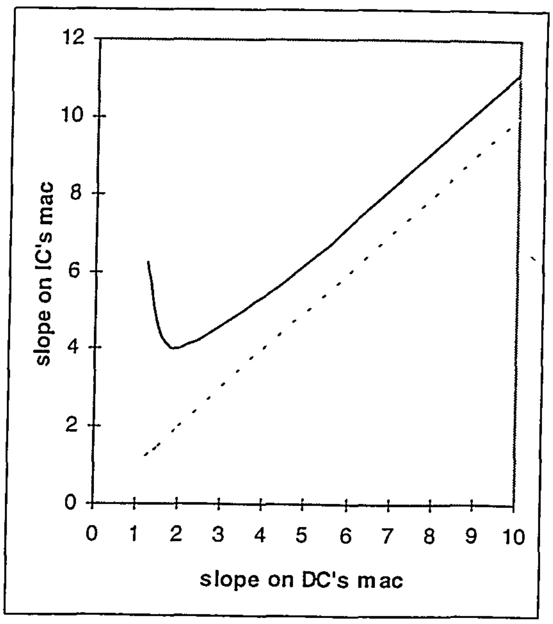
$$(2.12)\quad c_D\left(1-\frac{c_D}{c_D + c_I}\right) < (c_D - 1)\frac{c_D}{c_D + c_I} + 1$$

re-arranging results in:

$$(2.13)\quad -(c_D)^2 + c_D c_I - c_I < 0$$

This is a sufficient condition for negativity of (2.8) if $E_A < E_0$, and it shows that the effect of reduced baselines - and hence also JI - in the present setup rests solely on the relative relationship between the slope of the countries' MAC curves. It is difficult to make a firm conclusion from (2.13), but figure 4.1.1 illustrates equation (2.13) in a diagram with $c_D$ on the x-axis and $c_I$ on the y-axis.

**Figure 2 Equation (2.13)**




Lying below the full line in figure 2 secures that (2.13) holds and hence that tradability gains are increasing when baseline emissions decrease - that is when JI is implemented prior to the TQ regime. The dashed line shows the 45-degree line.

Figure 4.1.1 shows that DCs' gains will increase when their baselines fall, even if their MACs are slightly larger than ICs - the difference can, however, not be arbitrary since the slope on ICs MAC curve cannot be larger than the line indicates.

For an arbitrary allocation rule a more general (sufficient) condition to satisfy (2.11) leads by re-arranging (2.11) to the following;

$$(2.12)\quad \frac{E_D^A}{E_D^0} < \frac{c_D^{\ 2} + c_I c_D + c_I}{c_D c_I}$$

As long as this equation is satisfied then decreasing baseline, due to e.g. JI, will raise DCs' gains from trade given the cost function. This function enables me to show the inconsistency between Bohm's graphic illustration (figure 3.1.1) and his choice of cost function. If we denote the right hand side of (2.12) λ then assuming that allocations are equal baseline the left-hand side of (2.12) equals 1- hence if $\lambda$ is larger than 1, JI can increase DCs' tradability gains. This is a contradiction to figure 3.1.1, where baseline reduction involves decreasing gains. Using the present cost function actually allows DCs' gains to increase if JI is implemented prior to a TQ regime. The reason is that the dynamic perspective of accumulated abatement is not captured in the cost function.

Recalling the conclusions in Larsen, B and A. Shah (1994) it can also be verified by (2.12) that it is possible to have a situation where baseline reductions raise gains when allocations are based on population. If allocations are based on population Larsen, B and A. Shah (1994) show that allocations are likely to be larger than baseline for the DCs. This involves $E^A / E^0$ to be larger than 1. But given their assumption that MACs are equal for all countries; $c_I = c_D = c$, then $\lambda$ becomes:

$$(2.13)\quad \lambda = 1/c + 2$$

which is also likely to be greater than 1. It is then possible to fulfil (2.12) with population based allocations – i.e. it is possible to reproduce the result in Larsen and Shah (1994).

Finally if DCs are given allocation so that trade will make them equally well off then as noted above $E_D^A = \frac{1}{2}(E_D^0 + E_D^*)$. Inserting this in (2.12) shows that JI could have a positive effect on DCs' tradability gains if :

$$(2.13)\quad \frac{(E^* + E^0)}{2E^0} < \lambda$$

These analyses indicate that the effects of JI prior to a TQ regime are rather ambiguous and that quota allocation principles and differences in marginal abatement cost curves largely determine the results. The firm conclusion in Bohm's graphic illustration is inconsistent with his later analysis of tradability gains because this does not incorporate dynamics.

## 3. Estimates of tradability gains - an example.

Now if cost curves and allocation principles are the sole determinants of the effect of JI on DCs' incentives to join a TQ regime, then the true incentives could be calculated if data for cost curves and for allocation principle were available.

So far only rather rough estimates of the cost curves have been published and the quota allocation principle to be used if TQ are incorporated in the Kyoto Protocol has not yet been agreed upon. It is, however, our opinion that quota allocations are likely to be based on 1990 emission level, also if DCs - or at least some of the largest DCs like China and India - are included in the regime.

It may seem political unacceptable for the DCs to participate in a TQ regime with allocations based on 1990 emission level (see chapter 2) but what if it can be showed that they actually will gain from such a regime and furthermore that they might even improve their gains if JI is implemented prior to the TQ regime?

Musgrave (1994) has published data relevant for the cost function used in the above analysis, and we will use these to run simulations of China and India's gains in a TQ regime where allocations are based on 1990 emission level - both with and without JI prior to the regime. Table 2 show the data set.

**Table 2; data set**

| | baseline | slope on MAC |
|---|---|---|
| Japan | 238 | 4.89 |
| US & Canada | 1320 | 0.54 |
| EU | 815 | 1.02 |
| Eastern Europe and Russia | 1263 | 0.44 |
| **Total** | 3636 | 6.89 |
| average | 909 | 1.72 |
| China and India | 722 | 0.62 |

Source: Musgrave (1994)

To simulate a TQ regime we need cost functions, allocation rules and rules for quota unit price determination and trade determination. Above the cost functions were; $C(DC) = \frac{1}{2}c_D(E_D^0 - E_D^*)^2$ , the quota unit price and trade were determined through equalisation of MACs. The target for the TQ regime is to return to 1990 emission level. To keep from mixing emission estimates we simply assume that the 1990 level can be set to 15% below the baseline level in Musgrave's data. Global 1990 emission is thus 3.704 mill. T or 614 mio T for India and China and 3.091 mio. T for the ICs. It is further assumed that countries are given allocations equal to their 1990 level, and the data in the first to columns of table 3 show the emission and allocation data set.

**Table 3: Tradability gains with 1990 allocations.**

| | | | non-trading | | trading | | | |
|---|---|---|---|---|---|---|---|---|
| | Quota | baseline | Abatement | | | | | tradability |
| country | allocation | | demand | cost | abatement | price | trade | gains (cost) |
| India and China | 613.7 | 722.0 | 108.3 | 3,636.0 | 480.5 | 297.9 | -372.2 | -39,308.6 |
| ICs | 3,090.6 | 3,636.0 | 545.4 | 255,816.6 | 173.2 | 297.9 | 372.2 | 136,680.0 |
| TOTAL | 3,704.3 | 4,358.0 | 653.7 | 259,452.6 | 653.7 | | | 97,371.4 |

The allocation rule involves abatement demand on the two groups of countries, as shown in column 3, and if these were to be abated unilaterally, the cost would be as indicated in column 4[9]. Now if the quotas are allowed to be traded, the involved price will lead India and China wanting to abate 480,5 mio T and hence to supply 372,2 mio T for export. The ICs will be willing to demand the 372,2 mio T because the price is still lower than their MACs, and the result is that the total costs are more than half the non-trading case. India and China have even negative costs because the export revenue exceeds the abatement costs. The table thus illustrates the total individual gains from trade for both groups of countries. India and China actually have positive tradability gains (negative costs) and may therefore be induced to participation (For a similar set up of tradability gains see Barrett, S., 1992).

So far so good, but what will happen if JI had been implemented prior to the opening of trade? First of all India and China's baseline would be smaller and assuming that the emission reduction from JI projects in absence of JI would have been carried out in the ICs these countries' baseline will increase by the same amount. To show this effect we can shift 22 mio T from India and China's baseline to the ICs' baseline. Second JI could involve host countries MAC's to rise and donor countries' MACs to fall. This effect can be estimated by reducing the slope of ICs' MAC curve to 1,5 and increase India and China's to 0,8. The result is shown in figure 4 below.

**Table 4: Tradability gains with 1990 allocations and initial JI.**

| | | | non-trading | | trading | | | |
|---|---|---|---|---|---|---|---|---|
| | Quota | baseline | abatement | | | | | tradability gains |
| country | allocation | | demand | cost | abatement | price | trade | (cost) |
| India and China | 613.7 | 700.0 | 86.3 | 2,979.1 | 426.3 | 341.1 | -340.0 | -43,268.0 |
| ICs | 3,090.6 | 3,658.0 | 567.4 | 241,457.1 | 227.4 | 341.1 | 340.0 | 154,743.8 |
| TOTAL | 3,704.3 | 4,358.0 | 653.7 | 244,436.1 | 653.7 | | | 111,475.7 |

The last 4 columns are the most interesting and they actually show that India and China's gains have increased compared to the situation without JI. This is a result of an increased price that outnumbers a decrease in trade.

Of course this example is constructed more or less arbitrary, but it is though quite interesting that we can departure from a situation with absolute abatement demand put on the DCs' shoulders and end up with absolute gains that are larger for the JI case than for the case without JI.

The primary lesson from this chapter is that JIs' influence on the free rider problem is ambiguous. Bohm's indication that DCs incentives to join a TQ regime decrease when JI is implemented in advance is inconsistent with the analysis of tradability gains. If the question, however, is analysed in the model of tradability gains, we find that the answer rests on the relationship between DCs' and ICs' MAC curves and on the relationship between DCs' quota allocation and baseline emission.

A major restriction on the tradability analysis is that it does not capture the dynamic characteristics of the problem or the sequential negotiation pattern. A model to take this into consideration could be based on an extensive form game theoretic model. The purpose of the next chapter is to build a model within this context.

## Concluding remarks

The main force of the tradability analysis is that it is rather simple and therefore applicable to empirical analysis. Applied analysis guarantees that all relevant asymmetries are incorporated. The fact that a NTQ regime only including the ICs, has been in operation prior to a TQ regime has to be modelled. We did this by assuming that two different NTQ regimes could have been in operation; one without JI and one with JI. Shifts in baselines and MACs had to be modelled on as ad hoc basis.

More work on the empirical data in our example such as to model the Kyoto Protocol and make estimates of the JI level under different assumptions of the CDM, could make very interesting studies, but lies outside the scope of this paper.

The main disadvantage of the model is that it is static and that the cost function applies to a case without leakage. The large interdependence between countries' emissions can only be incorporated 'manually' by making assumptions of changes in baseline etc. A more comprehensive model would define the interdependence implicitly such as to reflect leakage effects and shifts in baseline due to JI[10]. Furthermore the model does not explain which quota allocation will be chosen or how the ICs' commitment ambitions could be affected through the opening of the CDM.

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## Endnotes.

[1] Bohm (1994a) rejects that this could be the case for JI between committed and non-committed countries because this situation is actually very different from a TQ regime.

[2] Baseline emissions are projected emissions in the absence of the relevant emission reductions.

[3] This assumption is discussed in the next section.

[4] The function captures increasing MACs in the sense that the larger current abatement the larger the MAC, but if there has been some abatements earlier, the MACs would be even larger. Bohm's figure (figure 3.1.1) actually shows the dynamic perspective because it considers movements on the MAC curve; when the cheap projects have been undertaken you move upwards on the MAC curve. There is therefore a missing link between the graphic illustration and his later model.

[5] This principle distributes a quantity $POP_i/POP_g$ of a global emission quota to country i. $POP_i$ is the level of country i's population and $P_g$ is the global level of population.

[6] see Hanley et al 1997 chapter 2.

[7] This condition is exactly what Bohm uses in his case 2 and shows in figure 9.4 but he makes a mistake in stating that the term should be $E_D^1 = \frac{1}{2}(E_D^0 - E_D^*)$. The above calculations show that $E_D^0$ and $E_D^*$ should be added and not subtracted which is also clear from Bohm's graphic illustration

(Bohm 1994). Where Bohm concludes that gains are positive the present more general set up shows that this is only the case if $E_D^1 > ½(E_D^0 + E_D^*)$.

[8] From (2.3) we have: $E_D^* = E^T - E_I^*$. From (4.3.5) we have $E_I^* = E_I^0 - \frac{c_D(E_D^0 - E_D^*)}{c_I}$ inserting these equations in each other, an isolating $E_D^*$ gives (2.7).

[9] The average MAC curve slope according to table 3.5.1 are used for the IC's.
[10] This would involve that the connection between the emission of country 'i' and country 'j' would be arguments in the payoff function.

Risø-R-1184(EN)

*The Danish Energy Research Programme 1998*

# $CO_2$ Permits in Danish and European Energy Policy


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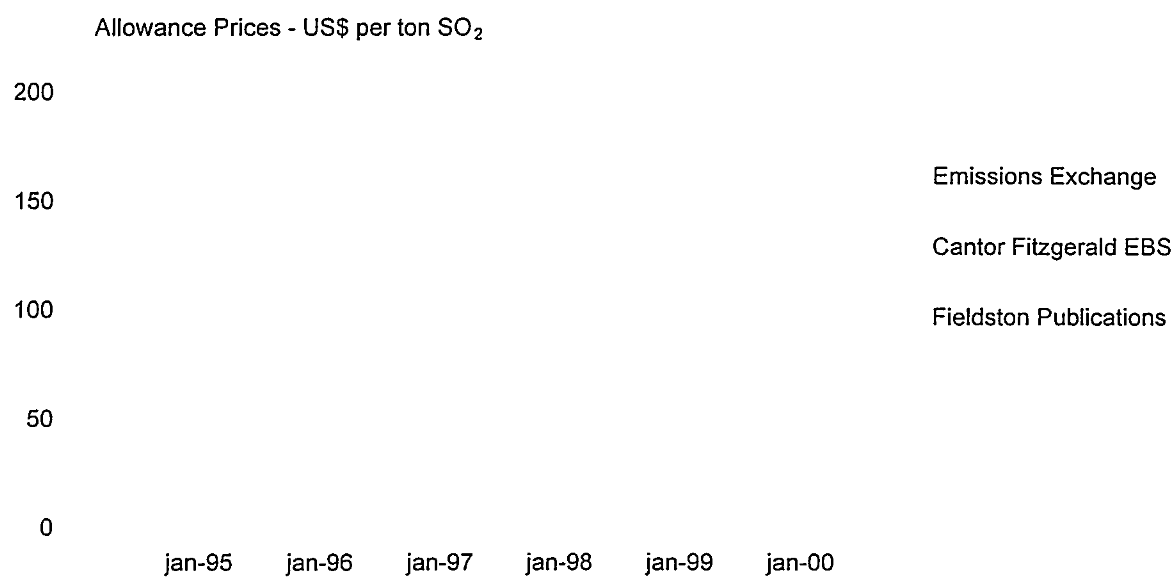


*DRAFT 10 May 2000*


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# 8 Quota prices

How high or how low will the $CO_2$ quota prices be if a system of tradable permits is agreed on? What are the costs to society of $CO_2$ reductions under alternative assumptions on quota trade (or Joint Implementation and CDM)? These are important questions to politicians, power producers, energy intensive firms and consumers.

A number of model based studies have estimated quota prices and costs to society of conducting $CO_2$ reduction policies. The estimated prices and costs vary so much that it is difficult to extract any clear message. The variance in results suggests that researchers (and model users) even disagree on assumptions of importance to the magnitude of quota prices and costs. In some of the studies there seem to be confusion with respect to the use of different cost concepts: It is not at all clear what is meant by "costs of $CO_2$ reduction", "costs to society", "quota prices". Often "costs" are presented as "costs per ton $CO_2$ reduced" and interpreted as an estimate of quota prices, but the cost concept include macro economic effects of quota prices.

Section 8.3 illustrates that estimates how costs to society and estimates of quota prices can vary from one study to another. At least estimates of costs to society seem to vary in a systematic way, dependent on the type of model used.

The present analysis briefly discusses the use of different types of models to estimate quota prices, emission reductions and costs to society of reducing emissions (cf. Sections 8.1 and 8.2).

The main focus is on the limitations of the models with respect to estimating quota prices. It is obvious that national models cannot be used to derive quota prices on an international market. Estimates for example of EU quota prices require EU models. If $CO_2$ reductions outside the EU are cheaper than within the EU, and if it is possible to buy these $CO_2$ reductions for example through JI or CDM – this will affect the EU $CO_2$ quota prices. If countries conduct policies, which support renewables within power production, or support other initiatives, which reduce greenhouse gases, this will have an effect on the quota prices (cf. Nielsen, 1999). If there are important backstop technologies with respect to $CO_2$ reduction, and reductions of other greenhouse gasses, this may have an effect on quota prices.

The analysis demonstrates that there are important backstop technologies with respect to $CO_2$ reduction. If a backstop technology is the marginal $CO_2$ reduction technique on the market, the quota price will be equal to the $CO_2$ reduction cost of that backstop technology. If the models used to estimate quota prices do not model the relevant backstop technologies, the estimated quota prices may be too high.

The analysis demonstrates that in Denmark and in the EU the power-producing sector is significant with respect to $CO_2$ reductions; and furthermore that there are important backstop technologies with large emission reduction potentials. Knowledge of the backstop technologies and their $CO_2$ reduction costs (under given assumptions) can be used to infer upper limits to the $CO_2$ quota prices. This is done for Denmark and the EU, given a number of assumptions.

The present analysis stresses the importance of attention on backstop technologies – their emission reduction potentials and the prices at which they become profitable – in studies of quota prices and costs of $CO_2$ reductions. The present analysis indicates that failure to include backstop technologies may give quota price estimates that are too high and of limited value.

## 8.1 The cost of $CO_2$ reduction

Different types of models have been used to evaluate the cost of reducing $CO_2$ emissions to a given level. The models differ with respect to their foundation in the technical sciences, microeconomics or macroeconomics.

The technical models focus on energy producing techniques (especially within the power-producing sector) and the techniques associated with energy consumption. The models evaluate emission reduction efforts and the costs of changing the existing technologies with new and less $CO_2$ intensive techniques. The technical optimisation models describing the power producing sector optimise the power producing techniques for given prices on electricity, taxes, quota prices, etc.

The macroeconomic models evaluate the macroeconomic responses to $CO_2$ quotas, $CO_2$ taxes, TP, TQ, JI or other instruments. They focus on the effects on aggregate energy consumption, international competitiveness, industrial output, the macroeconomic activity level, etc.

The assumptions forming the models and the cost concepts used differ. But both types of models have relevance.

In Denmark and internationally both types of models have been used to analyse the same questions concerning costs to society of reducing greenhouse gasses. But there seems to be a systematic difference between the models with respect to the estimated cost: The technical models seem to estimate lower costs to society than the macroeconomic costs (cf. Jacobsen et al., 1996, chapter 2). Much effort has been done to integrate the models.

The present and the following section relates the concepts of quota prices, $CO_2$ reduction costs and costs to society of reducing $CO_2$ with the different types of models. It is important to be aware that these concepts do not cover the same.

The *quota price* is formed on a market where supply and demand for quotas are presented. The quota price is equal to the *marginal* $CO_2$ reduction cost on the market.

The *macroeconomic $CO_2$ reduction costs* – the *costs to society* – are the direct and indirect economic consequences of firms and consumers being forced to reduce emissions or to buy or sell quotas. $CO_2$ quota prices can be interpreted as $CO_2$ taxes on firms and consumers, and the wider economic consequences of these taxes can be analysed in the macroeconomic models.

For *given* quota prices the national macroeconomic models estimate the macroeconomic costs of the quotas. But if the national and international macroeconomic models are sufficient specific with respect to techniques and emissions, it is in principle possible to estimate the $CO_2$ tax – or the quota – which will imply that the $CO_2$ reduction target is reached.

National macroeconomic and technical models cannot estimate quota prices on quota markets, which include more countries.

Macroeconomic estimates of national and international quota prices have the advantage that there are feed backs between the quota market (prices) and energy consumption, economic activity, foreign competitiveness, etc. These feed back mechanisms are the more important the higher the quota prices and the larger the effects on energy consumption behaviour and macro economic activity. The amount of data needed for the international analysis may be considerable.

Marginal $CO_2$ abatement costs and $CO_2$ abatement costs curves can be estimated from *technical models*. Cost curves for all the countries participating in a quota system combined with country specific emission reduction targets will say something about the quota market, the amount of trades and the quota price. Cost curves are estimated for given activity level, prices and technological development. It is obvious that quota prices estimated by technical models reflect the assumptions of the technical cost curves.

It is typical that output from the one type of model is used as input in the other type of model. The technical models use activity levels, prices and perhaps elasticities from the macroeconomic models and the macroeconomic model use emission reduction potentials and microeconomic $CO_2$ reduction costs from the technical models.

## 8.2 Relations between quota prices and macroeconomic costs of $CO_2$ reductions

This section shows that there is no "one to one" relation between the size of quota prices and the macroeconomic costs of $CO_2$ reductions. And demonstrate why it is important to distinguish between quota prices and macroeconomic costs.

The higher the economic activity in a country, the more emissions (in general) and the more emission reductions needed to reach a fixed emission target for the country. On a national quota market higher economic activity *may* increase quota prices, because the price of the marginal emission reduction increases. But it is not at all obvious that an international quota price is affected. Even if the quota price is unaffected of an increased activity level, the macro economic costs may be higher.

Along the same lines, changes in the fixed emission target for the country do not necessarily lead to changes in quota prices. But the macroeconomic cost change.

A higher quota price may be less damaging to the macro economy, if the high quota price is coordinated between countries and the low quota price is not.

A given quota price will have different macroeconomic implications dependent on for example the structure of a country's industry. The extremes could be an economy, which produce emission-reducing technologies, and therefore would have an economic advantage of international policies towards emission reductions. Or an economy where firms and processes are exported to countries without environmental regulation.

Studies of macroeconomic costs of $CO_2$ reductions reflect that the time horizon analysed is short. The reason why policies to reduce the greenhouse gasses are conducted are that there are positive welfare gains in the long run. And that these gains are bigger than short-term economic costs.

The time perspective is also important with respect to the quota price: Investments in $CO_2$ reductions can be very expensive if the $CO_2$ investments are not coordinated with other investments or not planned properly.

## 8.3 Quota prices in selected empirical studies

Estimates of quota prices are important as measures of the costs of climate policy to the individual emitters of $CO_2$. Summing up to the national level estimates of quota prices are important as input in macroeconomic analysis of the costs to society.

The following presentation of a few estimates of the quota price is very brief. The purpose is to show that estimates differ a lot. All the different estimates of the quota prices may be "correct" given the different assumptions. But it leaves the reader rather confused – and with a need for a method or guidelines to evaluate the quota prices. The following sections tries to develop such a method or guidelines concerning reductions of emissions.

A recent article by Criqui et al. (1999) use the POLES and EPPA models to estimate both costs of fulfilling the Kyoto agreement in different regions of the world and quota prices for these regions. Estimated quota prices are listed in Table 8.1. All prices are in constant 1990 US dollars or constant 1990 Danish currency (DKK). EPPA is a general equilibrium macroeconomic model and POLES is an energy system model with some common features with the "top-down" models. The abatement costs calculated by the POLES model are "sectoral cost", whereas the EPPA model takes the "full range of impacts of reduction policies" into account (Criqui et al., 1999, p 588). The size of the quota prices are much dependent on the model: According to Table 8.1 the EPPA model estimate prices twice the size of the POLES model prices for the Annex B market and EU market. In the article it is said that these differences are due to different reference scenarios: If the POLES reference scenario is used in the EPPA model, quota prices will be almost the same.

In 2010 the $CO_2$ reduction needed in the EU to go from the reference to the Kyoto target is 20 % in the POLES model and 29 % in the EPPA model. The quota prices are, following Table 8.1, 166 and 330 \$/ton C respectively. Comparing the two models gives that reducing emissions 9 % more (to reach the same target) gives a quota price increase of 100 %! Will that be credible? It is difficult to say, without having anything to evaluate it against. (The amounts of emissions reduced are 204 and 308 million ton C in the two models).

*Table 8.1. Quota prices for year 2010*

| Region/Model | POLES | | EPPA | |
|---|---|---|---|---|
| World* | 21.3 \$/ton C | (41.9 DKK/ton $CO_2$) | 24 \$/ton C | (47 DKK/ton $CO_2$) |
| Annex B | 63 \$/ton C | (124 DKK/ton $CO_2$) | 127 \$/ton C | (250 DKK/ton $CO_2$) |
| EU | 166 \$/ton C | (326 DKK/ton $CO_2$) | 330 \$/ton C | (650 DKK/ton $CO_2$) |

Source: Criqui et al. 1999.

Notes: All prices are in constant 1990 US dollars or constant 1990 DKK.
Non annex B countries are assumed to have reduction target equal to their baseline.

A special issue of the Energy Journal (1999) is dealing with "The costs of the Kyoto Protocol: A multimodel evaluation". Thirteen different modelling teams use their particular model to analyse some standard questions:

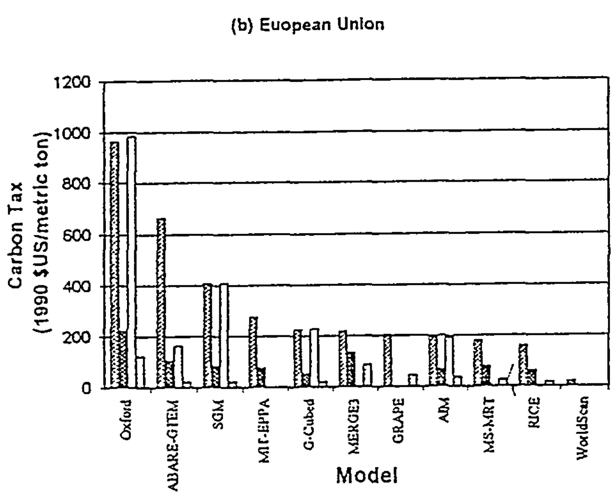
"First, each team was asked to run a "modellers reference" scenario, with modeller chosen GDP, population, energy prices, etc. This scenario was to assume no new policies other than those currently in effect (e.g., nothing new from Kyoto).

Second, the modelling teams were asked to run a number of stylised Kyoto scenarios varying on three dimensions: (i) The amount of international emissions trading assumed, (ii) The availability of sinks and "other greenhouse gas" emission reductions to satisfy the Protocol's requirement, and (iii) The required emission reduction beyond 2010."

The modelling teams estimate emission quota prices (carbon taxes) for different areas. With respect to the European Union the results are summarised in the following Figure 8.1 showing four different emission trading scenarios: 1. No international trade, 2. Annex 1 trading, 3. "Double Bubble", i.e. separate EU and separate "rest of Annex 1" trade, and 4. Global trading.

The EU carbon tax in the no international trade scenario is equal to the quota price in the "Double bubble" EU emission trading scenario (there may be minor differences). It is seen that there is an extreme variance between the most optimistic (<20 \$/t C = 5 \$/ton $CO_2$) and most pessimistic price estimates (>900 \$/t C = 245 \$/ton $CO_2$). Apart from the most optimistic model study, all the quota prices exceed 300 DKK/ton $CO_2$ (175 \$/ton C, exchange rate 6.19 DKK/\$). The Annex 1 trading scenario in most cases more than half the model based quota prices. This is to a large extent due to Russian "hot air".

The different quota prices of course reflect the different reference scenarios, assumptions and models. In principle all the quota prices can be equally relevant, but it could be very convenient to have a method or guidelines to evaluate the empirical relevance of the different outcomes.




Source: Weyant and Hill (1999)

*Figure 8.1. Year 2010 Carbon Tax Comparisons*

Table 8.2 describes the results of three Nordic model based studies of quota prices on a Nordic or a national market. Again the quota prices reflect the assumptions and models. What could be interesting to evaluate is the development of quota prices over time, and the very high quota price in 2020 in the Delmark study: According to Hauch (1999) an important difference between his own analysis of Sweden and Delmark's is that Hauch assumes that Sweden import electricity from the other Nordic countries. But why can Sweden not invest in the same power producing technologies as the other Nordic countries and bring the quota price down?

*Table 8.2. Quota prices in three Nordic studies*

| Analysis | Amundsen | Delmark | Hauch | Hauch |
|---|---|---|---|---|
| Model type | Partial equilibrium | General equilibrium | General equilibrium | General equilibrium |
| Market | Nordic[1] | Sweden | Sweden | Nordic[1] |
| Sectors | Power sector | Power sector | All | All |
| Reduction relative to target | Swedish nuclear power phase out, 1990 emission level | Swedish nuclear power phase out, 1990 emission level | Swedish nuclear power phase out, Kyoto (EU) targets[1] | Swedish nuclear power phase out, Kyoto (EU) targets[1] |
| Year for quota price(s) | 2000 | 2000,2020 | 2000,2020 | 2000,2010,2020 |
| reduction in pct. of reference | | | | year 2010: 26 % year 2020: 38 % |
| Quota price[3] | 65 DKK/ton $CO_2$ | Year 2000: 125 DKK/ton $CO_2$ Year 2020: 1045 DKK/ton $CO_2$ | Year 2000: 62 DKK/ton $CO_2$ Year 2020: 680 DKK/ton $CO_2$ | Year 2000: 75 DKK/ton $CO_2$ Year 2010: 340 DKK/ton $CO_2$ Year 2020: 600 DKK/ton $CO_2$ |

Sources: Amundsen (1999), Hauch (1999)

Notes: 1) Sweden, Norway, Finland and Denmark. 2) The EU distribution of the Kyoto target implies that Denmark reduces emissions by 21 % compared to a revised 1990 level. The other Nordic countries have reduction targets close to their 1990 emission level. 3) Prices are constant 1990 prices.

## 8.4 A method to evaluate the size of quota prices

Quota prices are results of supply and demand for emission quotas and indirectly results of supply and demand for emission reductions. Estimates of a future $CO_2$ quota price may be given by the intersection of supply and demand curves for $CO_2$ reductions. But supply and demand curves are difficult to construct because of the amount of data needed.

With respect to the power producing sector estimates of future quota prices are often based on technical optimisation or simulation models describing the existing power producing system and a number of alternative investment possibilities. A model based supply curve for $CO_2$ reductions can be constructed from registering the changes in the models emissions following different levels of quota prices. Of cause the supply curve reflects the alternative investment possibilities given in the model, fuel input prices, prices on electricity, and all the other assumptions of the model.

The method used in this section to evaluate the size of quota prices is to analyse important backstop technologies with respect to $CO_2$ reductions. *These backstop technologies may form a maximum-price supply curve for $CO_2$ emission reductions.* Given that these backstop technologies have large emission reduction potentials this supply curve may have large flat segments. The cheaper the backstop technologies – with respect to $CO_2$ reductions – the more likely it will be that the backstop supply curve will be close to, or even equal to, the "real" supply curve for $CO_2$ reductions.

The idea is illustrated in Figure 8.2, which shows prices and emission reduction potentials for three backstop technologies. At a price equal of P(b3) there is a reduction potential of z-y. y-x is the reduction potential for a backstop technology, b2, with $CO_2$ reduction costs equal of P(b2), and x-v is the potential at a quota price equal of P(b1). Figures are constructed so that the reduction potentials can be added. Together the tree backstop technologies have a reduction potential of (z-v).

Assume a tradable emission quota system. Then, *if the "demand" for emission reductions is between z-y, the quota price can never exceed P(b3)*, which is the price of the cheapest backstop technology. If the required level of emissions are between x and y the price will not exceed P(b2), and given a required emission level between v and x the price will not exceed P(b1).

If the emissions reduction potentials for the three backstop technologies are significant compared to the total reduction requirements, and if the $CO_2$ reduction costs are relatively low compared to other possibilities, one of these prices could be a good estimate for the emissions quota price. At least the prices of the backstop technologies will form maximum quota prices within different ranges of the total level of emission reductions.

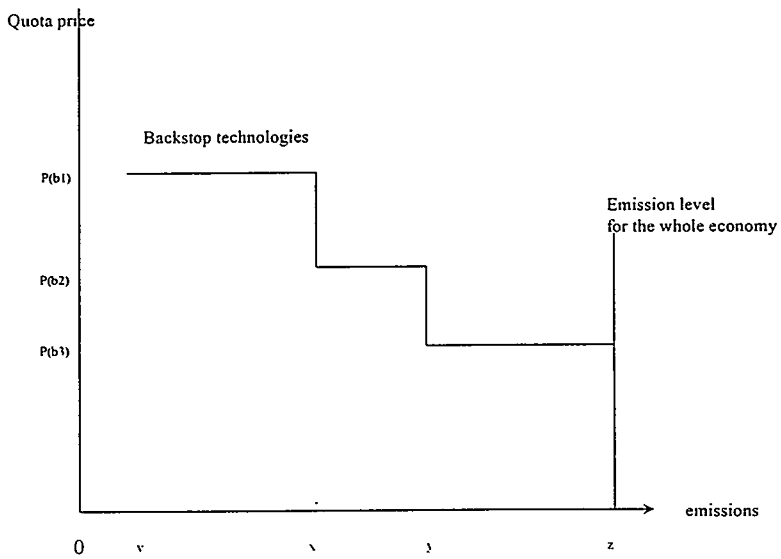



*Figure 8.2. Backstop technologies, prices and potentials*

The method can be motivated by at least two different arguments:

Knowledge of the emission reduction costs for backstop technologies with a large reduction potential (relative to the required reductions) can be used to question for example model based quota prices, which are either much higher or much lower than costs for the relevant backstop technology.

Part of the explanation why prices of American $SO_2$ quotas fell much below the predicted level was the presence of cheap backstop technologies with a huge emission reduction potential. But also investments in high cost emission reductions options[78] based on false expectations of high $SO_2$ quota prices (partly justified on the predicted high $SO_2$ quota price) played a role (Ellerman, 1998). The irreversibility of the investment decisions increased the supply of quotas at sunk costs (implying an outward shift in the supply curve). Because of the 'over-investment' in high cost emission reduction methods, the

[78] The backstop technology in question is "scrubbers", which clean $SO_2$ emissions to air.

marginal $SO_2$ reduction technique was a low cost technique. Table 8.3 copied from Ellerman (1998) summarises reduction costs and emission reductions in the American $SO_2$ market. "..early studies of compliance cost estimated (prices) at about $300 per ton, although it was possible to find even higher estimates" In 1993 the auction clearing price was $131, in 1996 allowance prices were slightly below $70 and in 1998 again around $130 (Ellerman, 1998).

*Table 8.3 Reduction and compliance costs in 1995 (1995 $)*

| Method of compliance | Emission reduction | | Avg. cost | Min. cost | Max. cost | Total cost |
|---|---|---|---|---|---|---|
| | ton $SO_2$ | Percentage | $/ton | $/ton | $/ton | Million $ |
| Title IV Scrubbers | 1,733,743 | 45 % | 267 | 186 | 773 | 463.1 |
| Non-Title IV Scrubbers | 20,698 | 1 % | 65 | 65 | 65 | 1.3 |
| Coal Switching | 1,707,819 | 44 % | 153 | 60 | 297 | 261.3 |
| Non-cost Switching | 425,242 | 11 % | 0 | 0 | 0 | 0.0 |
| Total | 3,887,502 | 100 % | 187 | 0 | 773 | 725.7 |

Source: Ellerman, 1998.

The preceding section showed wide differences among predicted future $CO_2$ quota prices. Of course these differences reflect the different models and the different assumptions. Some of them may be compatible. But if there are important backstop technologies with large emission reduction potentials, and if the investment costs of these are well known, all the studies must be able to relate to this information. The intention behind the next sections is to develop, or demonstrate, a method that can be used to evaluate predicted quota prices and the assumptions of the models used. Section 8.5 describes $CO_2$ reduction costs and potentials within the Danish power producing sector. These reduction costs are used to say something about maximum quota prices in a purely Danish $CO_2$ quota system. The analysis is broadened to the whole EU in Section 8.6.

## 8.5 $CO_2$ reduction costs for the case of Denmark

Table 8.4 gives a brief impression of alternative costs of reducing $CO_2$ within the Danish electricity sector. Figures are calculated based on a number of assumptions as to for example the interest rate, which type of power production is substituted, and which level of capacity the new and substituted plant is run at. The sizes of the figures are highly dependent on the assumptions, which are therefore relevant in evaluating the figures:

*Table 8.4. Costs for $CO_2$-reductions in Denmark in 1996*

| Country/ Technology | Denmark DKK/ton $CO_2$ |
|---|---|
| Electricity export reduced by 50 % | 40 |
| Electricity export reduced by 100 % | 100 |
| *Fuel conversion* | |
| – coal to gas | 76 |
| – coal to straw, 10 % | 275 |
| – coal to straw, 10 % in separate boiler | 446 |
| | |
| *New capacity* | |
| Industrial CHP, gas | 326 |
| Central KAD, coal | – |
| Central GAD, gas | 129 |
| Central CC, gas | 93 |
| Wind mills, placed at land | 241 |
| Wind mills, offshore | 282 |

Source: Elsam, 1997.

The higher the interest rate the more expensive are new investments in $CO_2$ reductions.

A given investment in $CO_2$ reductions will reduce more $CO_2$ – and the $CO_2$ reduction costs per ton $CO_2$ will be cheaper – if the substituted plant is very inefficient and emits a lot of $CO_2$. Therefore, if figures are based on the assumption that the substituted plant is always the highest $CO_2$ emitter, the figures may be valid only at the margin and have little or no relevance with respect to large scale emission reductions: One should notice that the $CO_2$ reduction costs are dependent on the reference scenario and which investments have already been carried out.

If the calculations assume that the new investments are always operating at full capacity (irrespective of whether it is profitable or not), it is likely that the amount of $CO_2$ reductions will be higher, compared to a situation where the investments are run below full capacity: The larger the $CO_2$ reductions, the cheaper these may be.

For a detailed list of assumptions behind Table 8.4, readers are referred to ELSAM, 1997. Some of the important general assumptions are: An interest rate at 5 % pa., market prices of electricity (implying less than full capacity use) and market prices on input fuels. All costs are measured in constant 1996 prices. One implication of this is that improvements in technologies compared to the 1996 "levels", or more intense price competition in markets for certain technologies (wind mills) are not taken into consideration. But these factors may be significant for certain technologies and may press investment costs – and the $CO_2$ reduction costs – down. Real fuel prices are kept constant at their 1997 level. (This assumption is in line with projections for 1997 – 2010 in World Energy Outlook, IEA, 1998). Electricity prices are close to variable costs in conventional electricity production, meaning that there are no incentives in the electricity prices to invest in new capacity. This price assumption may be very realistic in a 'strategic' market, or a market with excess capacity, but increases the $CO_2$ reduction costs because investments in general are.less profitable.

The general impression of the costs for $CO_2$ reduction given in Table 8.4 is that the magnitudes of costs are valid within a relevant Danish $CO_2$ reduction range. The interest rate may be too low for private investors. Table 8.4 is further commented in the following subsections.

### 8.5.1 Reducing export

The level of the Danish electricity production has traditionally been closely related to electricity production in Sweden and Norway, and in particular to the Norwegian hydropower production. In some years Denmark is a net importer of Norwegian hydropower (wet years in Norway) and in other years Denmark is a net exporter of coal produced electricity.

The new Danish electricity act from May 1999 introduces a $CO_2$ emission quota (on an annual basis) on the Danish electricity producers. If this quota is violated the producers has to pay a fee of 40 DKK per ton $CO_2$. This fee will make it less profitable to produce electricity at marginal Danish coal fired power plants (it will not make coal fired power plants unprofitable in general). It is estimated (see chapter 6) that the fee will reduce Danish exports of electricity by around 50 %, given constant prices on electricity and constant export prices. Under the same assumption of constant export prices, and therefore sufficient international supply of electricity at that prices and sufficient cable capacity, a 100 DKK pr ton $CO_2$ fee will reduce Danish electricity exports to zero.

The new electricity law does not necessarily squeeze the marginal coal fired power plants out: If the international electricity prices are sufficiently high, production at these plants may still be profitable.

*A Danish fee will reduce Danish emissions, but not necessarily reduce global emissions*: if the Danish electricity export to for example Norway is substituted by Norwegian import of electricity produced by a technology which also emits $CO_2$, and maybe emits the same amount of $CO_2$, the global $CO_2$ reductions may be limited or be zero. On the other hand, if Norway instead of importing from Denmark import electricity from Germany, the German emissions will rise and put pressure on the German government to take measures to reduce emissions in order to fulfil the German Kyoto emission reduction target.

### 8.5.2 Fuel conversion

The economics behind fuel conversion depends on the technology of the power plant in question, and on the prices and emission factors of the substituted and substituting fuels. Fuel conversion may be very cheap or very expensive. In Table 8.4 a typical Danish coal fired condensing power plant is converted to either gas or straw. Conversion to gas is relatively cheap – around 80 DKK per ton $CO_2$ – whereas conversion to straw, for both technologies, is relatively expensive. The reason why conversion to straw – which is often a waste product in the agricultural production – is so expensive is the transportation costs, and the more complicated technology needed to make the straw fired power plant function properly (for example to avoid Dioxin and dangerous emissions other than $CO_2$).

Back pressure or extraction power plants have higher fuel efficiency than the condensing power plants, and of course the technical properties are different. But fuel conversion does not change the basic technical functionalities of the power plants. And assuming that the investments needed for fuel conversion are the same irrespective of the condensing or combined heat and power technology – we further assume that the $CO_2$ reduction cost of condensing power plants apply to combined heat and power[79].

[79] The intuitive reasoning behind this assumption is that fuel conversion is related to the input into the power plant, whereas the question of condensing, back pressure or extraction is related to the energy output of the plants.

Waste from households and biomass other than straw (for example wood chops and energy crops) have zero $CO_2$ emissions factors and may be used as fuels in the heat and power production. The table does not cover conversion to these fuels. But compared to the $CO_2$ reduction prices for the two straw technologies, wood chop prices will be lower and energy crop prices probably higher. This relation reflects relative prices of tree chop, straw and energy crop, and reflects that using straw in the power production is technically more difficult than using wood chops and energy crops.

### 8.5.3 Building of new capacity

The fuel efficiency of power plants has much to say regarding emissions. Even substituting old coal fired power plants with new coal fired may reduce emissions. Therefore building new power plants with a) high fuel efficiency and b) a low emission fuel type may be the cheapest way to reduce emissions. Alternatively new renewable capacity may be built. For example wind-mills or solar cells. In Denmark windmills are relatively cheap because of good wind conditions.

The table refers to a relatively new coal fired power plant with relatively high efficiency as reference. Therefore it makes no economic sense to substitute this type of power plant with another coal -fired power plant. The chosen reference gives the $CO_2$ reduction costs in the table more credit, as these numbers are applicable beyond the margin.

The relatively high $CO_2$ reduction price of industrial combined heat and power is due to the Danish industrial structure with many relatively small firms and few very energy intensive firms. Investments in the cheapest industrial combined heat and power plants have already been carried out.

The $CO_2$ reduction cost related to windmills may be exaggerated as the investment cost are declining due to falling prices of windmills. Falling prices are a result of the size of the markets for wind-mills, increased competition and improved technology. Included in the investment costs are investments needed to cope with the fluctuating nature of power production from windmills. These costs may be smaller the larger the electricity net and the more dispersed the wind conditions.

Building new power production capacity will in practice be a much slower way to reduce emissions than fuel conversion. Investments, risks and losses are far bigger – and the planning horizon is longer.

### 8.5.4 Prices in a national $CO_2$ quota market

At the national level the Danish *total costs* of reducing $CO_2$ will be at a maximum if no international trade is assumed. Given international – for example European trade – the Danish national costs of $CO_2$ reductions will be lower. That is, quota trade reduces costs at the national level.

An international – for example European – *quota price* may be higher or lower than a purely national – for example Danish – quota price. If the international quota price is higher Denmark will be net exporter of quotas, and if it is lower Denmark will be a net importer.

If emission reductions are cheaper abroad, and if it is possible to substitute international emission reductions for national, the international price of emission reductions will also be the price of quotas on a domestic market. If foreign emission reductions are cheaper than the cheapest domestic emission reduction, no emission reductions will be carried out domestically. And there will be no quota trade on the national market.

There have been several attempts to prognosticise quota prices using different methods and assumptions.

The method used in this paper may be useful when only limited information about emission reduction curves is available. The method used has got the advantage that it tries to identify the lowest upper limit to the quota price. And this information may be very valuable to planners and firms – especially if the quota price identified in this way is relatively low.

In short the method is to focus on already known backstop technologies. That is, to select a few technologies, with great emission reduction potentials within the analysed area, and see at which quota prices these technologies will be profitable. The price estimates combined with estimates on emission reduction potentials can tell something about likely price ranges for emission quotas.

The European Union must follow the Kyoto protocol in reducing emissions by 8 % compared with the 1990 emissions level.

Within the European bubble Denmark has agreed to reduce emissions by 21 % compared to an adjusted 1990 level. .

The question analysed in this section is what will the quota price be on a purely national $CO_2$ quota market? Denmark is taken as an example, but exactly the same analysis could be carried out for all the EU countries.

Assume no substitution of foreign emission reduction for national. That is, only emission reductions carried out nationally will be accounted for, and the national emissions must not exceed the Kyoto targets.

The energy sector is by far the most important emitter of greenhouse gasses. According to the table below 68 % of Danish emissions of greenhouse gasses in 1994 originated from the energy sector and around 16 % from transport (Fenhann et al., 1997 and NERI, 1997, p. 40).

So, even though electricity production and export in 1994 was considerable and the table may therefore overestimate the contribution from the energy sector, emission reductions in the energy sector are important factors in a national Danish strategy to reach the Kyoto and EU emission targets.

*Table 8.5. Greenhouse gas emissions in 1994 apportioned by sector in percent of total emissions.*

| Sector | Percent of total emissions |
|---|---:|
| Energy | 68 |
| Transport | 16 |
| Agriculture | 16 |
| Waste | 3 |
| Forestry | -6 |
| Industry | 2 |

Source: Fenhann et al., 1997.

Assume a national Danish $CO_2$ quota market within the electricity sector alone. And assume the extreme situation that this sector is the only sector to reduce emissions. If Denmark has to fulfil the EU reduction target, the $CO_2$ reduction target in 2010 for the power producing sector should then, given the assumptions below, be in the range of 31 to 62 %

The electricity sector reduction target of 31 % is calculated in the following way: total national emissions are the same in 2010 as in 1990 and the share of the energy sector is 68 % in 2010. The national reduction target of 21 % is fulfilled by the electricity sector alone.; (100-79)*100/68 = 31 % The 62 % is calculated under the assumption that total national emissions have increased by 15 %.[80] in 2010 as compared to 1990, and the share of the energy sector is 50 % in 2010; (115-79)*100/(.5*115) = 62 %

How can these reduction targets be reached, and at what prices?

Following Table 8.7 what happens within the power producing sector, when quota prices rise (or a fee is introduced), is that the Danish electricity export diminish. This effect is of course only seen in years with electricity export, and presupposes that no other countries relevant for the electricity import or export introduces $CO_2$ taxes, quotas or emission trading. So production on marginal Danish coal fired power plants decrease. By how much emissions are reduced by reducing exports is difficult to say, but Danish electricity export was in the period 1984-1997 7 % of total Danish electricity production (Statistisk Tiårsoversigt, 1996 og 1999). Given this average, if the Danish electricity export vanished this would reduce emissions by at least 7 % (the marginal electricity production is more $CO_2$ emitting than the average).

At a quota price of 80 DKK/ton $CO_2$ fuel conversion will be profitable (cf. Table 8.4). Assuming that approximately 60 % of Danish power production, in a "normal" year without electricity export, is coal based (cf. Table 8.6), conversion from coal (95 ton $CO_2$/TJ) to natural gas (57 ton $CO_2$/TJ) would reduce emissions by 28 % (.6*(95-57)/79, where 79 is the average ton $CO_2$ emission/TJ in Danish electricity production. Converting orimulsion (80 ton $CO_2$/TJ) to natural gas would further reduce emission by 3.5 %

*Table 8.6. Total electricity generation by energy source, net export and import in 1997.*

| Energy source | TWh | Percent of total excl. export |
|---|---|---|
| Import | 0.0 | |
| Export (assumed coal based) | 7.3 | |
| Coal | 27.2 | 58.0 |
| Oil | 1.0 | 2.9 |
| Natural gas | 7.0 | 20.1 |
| Wind | 1.9 | 5.5 |
| Biofuel | 0.5 | 1.4 |
| Orimulsion | 4.2 | 12.0 |
| Danish electricity generation | 41.8 | |
| - excluding (coal based export) | 34.8 | 100.0 |

Summing the emission reductions from the decrease in exports (a fee of 100 kr/ton $CO_2$) and fuel conversions (there is no double counting) gives a total of 38.5 %. of total emissions within the electricity sector. This reduction should in principle – and given 1997 market prices for coal, natural gas and oil – be obtainable at a quota price below 100 DKK/ton $CO_2$.

At a quota price around 100 DKK/ton $CO_2$ (93 DKK. in Table 8.4) it will be profitable to substitute even relatively new coal fired power plants with new combined cycle natural gas

[80] The EU assumes an increase in emissions of 14 pct. over the same period in European Economy, no. 51, 1992.

power plants. New power plants have the advantage (compared to fuel conversion) of higher fuel efficiency. So if for example gas prices rise, this will make the construction of new power plants relatively more attractive compared to fuel conversion.

A $CO_2$ quota price of 100 DKK/ton $CO_2$ increases electricity prices and reduces electricity demand. The price increase depends on how $CO_2$ polluting the power sector is, and to what extent the quota price is reflected in electricity price increases. If the average $CO_2$ emissions from Danish electricity production in 1999 was equal to 0.8 ton/MWh a fully reflected quota price of 100 DKK/ton $CO_2$ would raise electricity prices in Danish industry and households by approximately 20 % and 6 % (differences are due to different tax levels and price discrimination). Table 8.7 assumes that consumer prices of electricity increase by on average 10 %.

A demand elasticity equal to -0.27 (as estimated in the Indus III model (1998), modelling energy consumption within Danish industry) means that if electricity prices rises by 1 %, electricity demand will fall by 27 %. If electricity demand and production fall by 27 %, emissions will fall by at least this percentage.

Included in the $CO_2$ reduction costs for windmills are cost to compensate for the fluctuating nature of wind power production. Therefore the windmills in the table in principle can substitute conventional power production.

*Table 8.7. Emission reductions at quota prices below 250 kr/ton CO2. Different scenarios. Denmark*

| | Quota price per ton $CO_2$. Approximately | Decrease in exports | Decrease in marginal production | Decrease in $CO_2$ emissions within electricity sector |
|---|---|---|---|---|
| **Change in demand for electricity** | | | | |
| Decrease in foreign demand (average year) | 100 DKK | 100 % | 7 % | > 7 % |
| Decrease in domestic demand for given elasticity | 100 DKK | | 2.5 %** | > 2.5 %** |
| Decrease in domestic demand for given elasticity | 250 DKK | | 6.3 %** | > 6.3 %.** |
| **Change in power production** | | | | |
| 75 % coal substituted by renewables*** | | | | |
| 25 % coal converted to gas | < 300 DKK | | 0 | 60 %* |
| 50 % coal substituted by renewables*** | | | | |
| 50 % coal converted to gas | < 250 DKK | | 0 | 49 %.* |
| 100 %coal converted to gas | < 100 DKK | | 0 | 28 %.* |

* The decrease in foreign electricity demand is subtracted before calculating the emission reduction. Therefore the decrease in exports may be added to this figure. The decrease in domestic electricity demand is not subtracted before calculating the emission reduction. Therefore the decrease in domestic demand cannot be added to this figure.

** Numbers are calculated for a demand elasticity in electricity consumption equal to -.27. Feed back effects are *not* taken into account, which it should be especially when considering big quota prices. Elasticities may be smaller when more than marginal changes in consumption prices are considered.

*** It is assumed that wind power substitutes coal fired condensing power production (i.e. up to a maximum of 55 percent of total Danish electricity production).

At quota prices of around 250 DKK/ton $CO_2$ wind mills will be profitable. As the reference to the wind mills is a relatively new coal fired condensing power plant, it is in principle possible, at this price, to substitute all the coal fired *condensing* power plants with wind power production (provided that the wind conditions where the new mills are placed are good enough). Coal fired back pressure and extraction power plants can not directly be substituted by wind power, but may be substituted by straw, waste, wood chops or other renewables. In the table above different alternatives are shown.

It may seem relatively extreme to let the coal based electricity production be substituted by 50 or even 75 % renewables. But remember that even if coal was 100 % substituted by renewables there would still be 35 % oil, natural gas and orimulsion based electricity production. The examples suggest a different mix of fuel conversion and renewables and give a maximum quota price. But it is important to note that if a quota price of for example 300 DKK was settled on the market, the investors and their investment behaviours would decide the optimal mix of $CO_2$ reducing technologies.

Taking the 50 % fuel conversion/50 % wind mill (renewables) production as an example, the table may be read in the following way: The stop of electricity export reduce emissions by at least 7 % in an average year (1984-1997). The specified changes in the power production structure adds 49 % reduction to this figure. So emissions within the sector will fall by at least 56 % But higher electricity prices will cause domestic electricity demand to fall. A very rough estimate of electricity price increases, a rough use of elasticities, and no use of feed back mechanisms, would suggest a 6 % decrease in domestic electricity demand and a higher decrease in emissions. Given the 6 % decrease, total emissions will fall by 59 % instead of 56 % (avoiding double counting). The quota price is below 300 DKK/ton $CO_2$.

Looking at the emission reduction costs and potentials in the rest of the economy – not just the electricity sector – complicates the analysis: Technologies are more diverse, potentials are smaller and consumption patterns differ. Macroeconomic demand elasticities may be a very easy way to represent aggregated responses of other sectors to a given quota price. Car driver's response to increased gasoline prices, consumer's response to increased oil and gas prices etc. tell how drivers and consumers reacted to price increases in the past, and tell something of past potentials for energy savings. One of the problems using demand elasticities is whether these elasticities are valid for very large price changes.

A quota price of 100 DKK/ton $CO_2$ raises the price of gasoline by 0.24 DKK/l or 3-4 %. Given a demand elasticity of approximately -0.5 as estimated in the ADAM model (Danmarks Statistik, 1996), this quota price will reduce emissions from private cars by 1.5-2 %.

According the ADAM and Indus models the fuel price elasticity within Danish industry, the primary sectors and transport industry is approximately -0.25. If this elasticity holds true fuel consumption may fall by as much as 10 percent following a $CO_2$ quota price of 100 DKK/ton $CO_2$.

The macroeconomic responses and costs of Danish quota prices at for example 100 DKK/ton $CO_2$ depend on the design of the system.

To conclude on a national Danish $CO_2$ quota price:

As the main emitter of $CO_2$, the power sector has to reduce emissions considerably. At quota prices below 300 DKK per ton $CO_2$, the power generating sector is capable of reducing by far the largest part of the Danish $CO_2$ reductions needed to fulfil the Danish reduction commitments. Even at a quota price of 100 DKK per ton $CO_2$ emissions within the power generating sector can be reduced significantly. This is due to in- and external decrease in electricity demand, fuel conversion and substitution of old capacity with new.

If wind power in large scale is promoted by policies other than $CO_2$ emission quotas, the price of $CO_2$ emission quotas will almost certainly not be higher than the $CO_2$ costs of fuel conversion as this is a technology with a very large emission reduction potential. It is likely that the quota price for the power sector, and the whole economy, will be *equal to* the $CO_2$ costs of fuel conversion.

## 8.6 Estimated price range for EU $CO_2$ emission quotas

An exact estimate of future quota prices on a European $CO_2$ emission quota market is impossible to give. The price will be dependent on $CO_2$ reduction costs within and outside the EU-countries, the country specific levels of economic activities and how much to be reduced. Below we try to give price ranges within which the quota price alternatively will be – under different conditions. Of course the more narrow these price ranges, the more informative the analysis.

The analysis is very similar to the analysis above of a national Danish $CO_2$ quota system. But of course the uncertainties with respect to the quota price are bigger. It may be easier to overlook important country-specific emission reduction potentials. Liberalising European energy (especially electricity) markets may have great emission reduction potentials and implications for a quota price. Fuel prices may be sensitive to for example large-scale fuel conversion from coal to gas.

The $CO_2$ quota prices will be extremely dependent on the possibilities of buying emission reductions outside the EU: Prices at an EU quota market will not be higher than alternative, comparable prices on emission reductions outside the EU.

To limit the analysis it is assumed in what follows that only emission reductions within the EU will be accredited. It will be highly relevant later to loosen this assumption to analyse whether the European quota market will survive "competition" from outside, and to analyse the price implications.

Two "areas" are especially interesting with respect to $CO_2$ emission reductions, because of a considerable contribution to the overall problem: The power generating sector and $CO_2$ emissions from transport. Within the EU the power generating sector contributed with 31 % of total $CO_2$ emissions in 1990, and this percent is expected to increase to around 38 in 2010 (cf. European Economy, No 51, May 1992). According to the same source, $CO_2$ emissions from European transport contributed with around 24 % in 1990 and this share is expected to remain constant. Total $CO_2$ emissions are expected to increase 14 % over the years 1990-2010. So if the EU, following the Kyoto target, must reach a reduction in its emissions by 8 % before 2010 (compared to the 1990 emission level), this reduction could be achieved by either:

- reducing $CO_2$ emissions from the power generating sector by 51 %, or
- reducing $CO_2$ emissions from cars with 80 %, or
- reducing $CO_2$ emissions from cars and the electricity sector by 31 %.

These three extreme alternatives assume that no other sectors reduce their $CO_2$ emission compared to the reference scenario, and the other greenhouse gases mentioned in the Kyoto protocol are reduced to their 1990 level.

If it is possible to find a minimum marginal $CO_2$ reduction price of one or more of these reduction strategies, the minimum price will be the maximum price of European $CO_2$ quotas.

The following analysis focuses on the power-generating sector. But it is worth noting that consumer prices on energy – electricity prices, prices on gasoline, etc. – differs widely within the EU (see for example statistics in Energy Prices and Taxes from the IEA), and so does energy intensity in for example private consumption. Price differences are due to monopolised energy markets, taxation, countries endowments with primary fuels, environmental considerations, competitiveness of domestic industries etc., etc. According to main stream economics it is reasonable to believe that these price differentials has resulted in different energy consumption patterns among the EU countries. Therefore narrowing the price differentials by rising the lowest energy prices may have large emission reduction potentials. This effect may be reflected in different sizes of price elasticities amongst EU countries. (Effects on energy consumption of very low energy prices are seen in the former Eastern Europe).

### 8.6.1 Reducing $CO_2$ emissions from the power generating sector

Table 8.8 shows by which fuel electricity is produced within the EU.

*Table 8.8. Electricity generation in the EU by fuel. Year 2000.*

| Fuel | Fuel input, % | Electricity production, % |
|---|---|---|
| Solids | 20.7 | |
| Oil (including refinery gas) | 11.4 | |
| Gas | 16.9 | |
| Biomass – Waste | 3.5 | |
| Thermal incl. biomass | 52.5 | 52.5 |
| Hydro and wind | | 13.2 |
| Nuclear | | 34.3 |

Source: Shared Analysis Project, Vol.5. Appendix.

Very rough estimates suggest that: If we assume that the main part of emissions from the power generating sector originates from coal fired power plants, fuel switch to natural gas will reduce emissions by around 40 % (Coal is assumed to have an emission factor of 95 tonne $CO_2$/TJ and natural gas 56.9 tonne $CO_2$/TJ. ((95-56.9)*100/95=40.1)). If 50 % of the emissions stem from coal[81], the reduction will be 20 % (95-56.9)*20.7*100/(20.7*95+11.4*74+16.9*56.9)= 20.8 (Remember that nuclear power, biomass, renewables and hydro power has got no emissions). If both oil and coal fired power plants fuel switch to natural gas emissions will be reduced by 26 %.

Alternatively, if an extra 10 % of the total electricity production is supplied by renewables (compared to the reference), and this production substitutes coal fired power plants, this would reduce emissions by 20 % if coal fired electricity production is 50 % of total electricity production and coal is the main cause of $CO_2$ emissions within the EU power producing sector ((95-0)*.1*100/(.5*95)). Emission reductions would be 26 % if coal fired electricity production was 20 % (and the percentages for gas and oil was 16.9 and 11.4) of total electricity production (cf. Table 8.8).

The following Table 8.9 is almost identical to Table 8.4 It shows prices on $CO_2$ reductions within the European power-producing sector under the same assumptions as in Table 8.1. The question is whether fuel conversion prices and investments in new capacity are the same in the rest of EU as in Denmark.

[81] This assumption is in line with table xx and fuel input shares to solids (coal), oil and gas at 20.7, 11.4 and 16.9 % 52 % of emissions will stem from solids (coal), 22 % from oil and 26 % from natural gas.

Of course there are differences between the EU countries. The power producing sectors differs much with respect to the share of hydro, nuclear, wind and thermal power. But from a $CO_2$ reduction point of view it is only the thermal power production, which is interesting to look at either to fuel convert or to substitute by more efficient power plants or renewable energy.

The efficiency of Danish power plants is high compared to the average efficiency within the EU. This is an argument for low EU $CO_2$ reductions costs compared to the Danish costs. Maybe the potentials in fuel switch to wood chops are higher in the EU than in Denmark. Prices on waste, straw and wood chops may be determined on local markets and may differ widely between the EU. But otherwise, given the same fuel input prices, electricity prices and prices on investments, and given the relative efficient reference coal fired power plants, the $CO_2$ reduction costs in the table should be the same in the different EU countries.

Effects on $CO_2$ reduction costs from different price assumptions are shown in column 3 in Table 8.9. Coal prices are the same as in column 2. Prices on gas and electricity are higher, 27 and 66 %, and prices on straw are lower, 56 % The relative price of electricity is much higher in colum 3 than in colum 2, because it in comum 3 is assumed that the electricity prices increases to a level where it is profitable to invest in new power plant capacity. The market prices in column 2 are near variable costs for conventional electricity production.

Higher relative gas prices make fuel conversion from coal to gas more expensive and $CO_2$ reduction costs higher. Lower prises on straw, lowers the $CO_2$ reduction costs. $CO_2$ reduction costs on new gas fired power plants increase with increasing gas prices and fall with increasing electricity prices. The net effect is falling $CO_2$ reduction costs. Investments in windmills are more profitable – also from a $CO_2$ reduction point of view – the higher the electricity prices.

The changed fuel and electricity prices change the ranking of technologies with respect to the cheapest $CO_2$ reduction costs. But fuel substitution from coal to gas, and investments in an increased share of renewables, are still possible at relatively low costs. All $CO_2$ reduction prices in column 3 are below 307 DKK/ton $CO_2$.

*Table 8.9. Prices for $CO_2$-reductions in EU*

| Country/ Technology | EU DKK/ton $CO_2$ Market prices 1997 level | EU DKK/ton $CO_2$ Changed relative fuel prices |
|---|---|---|
| ***Fuel conversion*** | | |
| – coal to gas | 76 | 190[1] |
| – coal to straw, 10 % | 275 | 136[2] |
| – coal to straw, 10 % in separate. boiler | 446 | 307[2] |
| | | |
| *New capacity* | | |
| Industrial CHP, gas | | |
| Central KAD, coal | 0 | 0 |
| Central GAD, gas | 129 | -70[3] |
| Central CC, gas | 93 | -90[3] |
| Wind mills, placed at land | 241 | 143[3] |
| Wind mills, offshore | 282 | 184[3] |

Source: Elsam, 1997.

Notes: 1) Coal prices are the same as in column 2. Gas prices are 27 % higher. 2) Coal prices are the same as in column 2. Prices on straw are 56 % of the prices in column 2. 3) Coal prices are the same as in column 2. Gas prices are 27 % higher. Prices on electricity are 66 % higher.

Table 8.10 combine the $CO_2$ reduction prices in Table 8.8 with very rough estimates of the EU potentials for $CO_2$ reductions. The $CO_2$ reduction costs are based on market prices for fuels. A quota price equal to 100 DKK is assumed to increase electricity prices with 6 % But this price increase is highly uncertain[82]. Given demand elasticities equal to -0.25 this price increase will result in a 1.5 % decrease in electricity demand (and production) and a more than 3 % decrease in $CO_2$ emissions from the electricity sector (if the marginal productions is assumed to be coal based).

A hundred percent fuel conversion from coal to gas gives a decrease in emissions from the power producing industry by 20 % The quota prise inducing this conversion would be under 100 DKK/ton $CO_2$. If an extra 10 percent of the electricity production were based on renewables this would reduce emissions by 26 %, if the marginal electricity production were coal based. The quota price inducing this would be below 300 DKK

The quota price giving incentives to extra 10 % renewables will also be an incentive to fuel conversion and maybe a higher percent of renewables. Fuel conversion may be very profitable at a quota price well above 100 DKK To the existing conventional power plant owners fuel conversion may be much more profitable than investments in renewables, for example wind mills. But to other investors windmills will be profitable and they will invest.

If capacity in the power-producing sector increases and electricity prices fall – quota prices may rise to compensate the electricity price fall and induce further investments.

Following the table, $CO_2$ emissions will be reduced by 33 % if quota prices induced extra 10 % renewables and 50 % fuel substitution from coal to gas Taking the demand effects into account would add an extra 5 % (if the marginal production is oil based).

Halving emissions from the EU power sector, which is what is needed to fulfil the Kyoto target (if the power sector is the only sector to reduce emissions, and if emission projections are as previously mentioned) imply heavy reliance on renewable energy. The "halving" could be implemented in the following way:

- Substituting coal based power production (20 % of total EU production) with (17 %) renewables (decrease in demand is 3.8 %).
- Substituting oil and gas based power production (28 % of total EU production) with renewables. Leaving the coal based power production unchanged.
- Some combination of the two alternatives above
- Converting oil based power production to gas, and substitution 14 % of coal production to renewables. (Decrease in electricity demand is 3.8 % coal based).

Whether it is possible to substitute almost all conventional coal based power production with renewables (at least 14 % of total electricity production) at a price not higher than 300 DKK/ton $CO_2$, is difficult to answer. With respect to wind power it depends on wind conditions, the size of the transmission net and the technical problems with the fluctuating wind power.

The new Danish electricity act demands that 20 % of Danish electricity consumption should be based on renewables (which in practice will say almost 20 % wind). Compared

[82] The 6 % is a little lower than the assumed Danish electricity price increase. The simple, but highly uncertain, reasoning is: European net taxes on electricity are lower than the Danish, but Danish electricity production is more $CO_2$ emitting. The first effect suggest a higher EU price increase than the Danish, the last effect a lower price increase. The net effect could be 6 %.

to Denmark the EU has got very little combined heat and power. This means: 1) that wind power in principle can substitute almost all the thermal power production, and 2) that it is easier to use conventional power plants to compensate for the fluctuating wind. (In Denmark much of flexibility of the electricity production is hindered by the production of heat).

In other EU countries conversion to biomass or other renewables than wind, may be cheaper than in Denmark.

The conclusions with respect to an EU quota price are:

As one of the main emitters of $CO_2$, the power sector has to reduce emissions considerably. At quota prices equal to the costs of fuel conversion or costs of investments in new conventional capacity (i.e. below 100 DKK per ton $CO_2$, given the assumptions in this section) the power generating sector is capable of reducing emissions by 20 % Given the emission projections hold, a 20 % emission reduction is the average reduction needed in all sectors to fulfil the EU Kyoto commitment.

If the EU power sector has to reduce emissions by much more than 20 %, renewables (hydro power or nuclear power) must be an important part of the strategy. There is a large EU potential for wind power at quota prices below 300 DKK/ton $CO_2$. It is possible that biomass is cheaper in the EU than in Denmark.

If renewables – for example wind power – is promoted by other policies than $CO_2$ emission quotas, the price of $CO_2$ emission quotas can be effected.

There is a large emission reduction potential in renewables; therefore it seems likely that an EU $CO_2$ quota price will not exceed the price of the marginal investment in renewables.

*Table 8.10. Emission reductions at quota prices below 300 DKK/ton $CO_2$. Different scenarios. European Union*

| | Quota price per ton $CO_2$ Approximately | Decrease in marginal production | Decrease in $CO_2$ emissions within electricity sector |
|---|---|---|---|
| **Change in demand for electricity** | | | |
| Decrease in EU electricity demand, for given elasticity and price increase | 100 DKK | 1.5 %** | 3 %*** |
| Decrease in EU electricity demand, for given elasticity and price increase | 250 DKK | 3.8 %** | 7 %*** |
| **Change in power production** | | | |
| Extra 10 % of electricity production based on renewables | < 300 DKK | 0 | 26 %* |
| 100 % coal converted to gas | < 100 DKK | 0 | 20 %* |
| Extra 10 % renewables 50 % coal converted to gas Increasing fuel efficiency | < 300 DKK | 0 | 33 %* |

* The decrease in domestic electricity demand is not subtracted before calculating the emission reduction. Therefore the decrease in domestic demand cannot be added to this figure.
** The effect is highly uncertain. Price increases are assumed lower and elasticities identical to the Danish, but percentage price increases and price elasticities may differ widely between countries, and the true effects may be higher or lower than the Danish. Feed back effects are *not* taken into account, which it should be especially when considering big quota prices.
*** It is assumed that the marginal power plant is coal based.

## 8.7 Conclusions on $CO_2$ quota prices

This sections conclusions with respect to the price on especially an EU quota market are listed below. All cost estimates are subject to a number of highly uncertain assumptions. Therefore these estimates must be interpreted with a high degree of caution. But having said that, we believe that the cost estimates do carry information.

***A precondition for trade on an EU market is a sufficient supply of quotas at prices, which are equal to or lower than alternative emission reduction opportunities.***

If CDM or Joint Implementation with countries outside the EU is a possibility, or if a system of quotas including other countries than the EU counties exists, it will be a precondition for trade on the EU quota market that there is a supply of quotas at the equilibrium price on the EU- market. That is, there must be at least one country within the EU, which have enough of low costs emission reduction options to fulfil their own international commitments and to sell quotas on an EU-market with profits. If emission reduction prices are lower outside the EU, there will be no trade on an EU market for quotas.

***Given trade on an EU quota market, and if EU tradable quotas are one out of more alternatives to the agents, there will be a linking between the quota price and prices of the alternative emission reductions.***

Prices on EU quotas will be equal to either the quota price on broader markets, or equal to the price on Joint Implementation emission reductions outside the EU, if these markets exists (i.e. in case of a broader than the EU-market for quotas exists or if Joint Implementation with countries outside the EU is a possibility).

***EU quota price when EU tradable quotas are the only alternative to reducing your own emissions to the agents.***

The EU quota price will be equal to the cost of the marginal $CO_2$ emission reduction within the EU as a hole.

### Upper limits to the quota price

If there are backstop technologies (i.e. emission reduction technologies) which have great emission reduction potentials within the EU, the $CO_2$-reduction price of one of these technologies may be the upper limit to the quota price. The cheapest backstop technology will be implemented first.

Within the EU power sector there is a great emission reduction potential in fuel switching and higher fuel efficiency. The prices of $CO_2$ reductions carried out through fuel switching range from 70 to 300 DKK per ton $CO_2$, depending on which fuel is substituted by which, the type of power plant etc. The price span is not defined as the largest possible, but as the price span within which the bulk of emission reduction potentials are to be found. And furthermore, at the upper limit of the price span another technology with great potential takes over.

The cost of extending the EU windmill capacity as a mean to reduce emissions, depends on the wind conditions where raised, and the technical possibilities of fitting fluctuating wind power into the overall power system. It will be technically possible to extend the EU wind capacity considerably at prices below 280 DKK per ton $CO_2$.

According the Kyoto Protocol the EU must reduce emissions by 8 % as compared to emissions in 1990. If it is technically possible to reach the 8 % target level through fuel switching in the power sector and increased wind power production, the upper limit to the EU quota price must be around the 280 DKK/ton $CO_2$, which is the estimated price of reducing emissions trough installing new wind mills. Even if it is not possible to reach the target level solely by using these two techniques – if it is likely that cheaper CO2 reduction technologies in other sectors can reduce the rest, then the upper limit to the quota price will still be given by the marginal wind power investment.

If windmills are the marginal $CO_2$-reduction investment on a European quota market, the price of the quotas will be around 280 DKK/ton $CO_2$. If fuel switch in the power sector will be the marginal investment, the quota price will properly be somewhere between 70 and 280 DKK/ton $CO_2$, depending on the price and potentials of alternative $CO_2$ reduction investments.

### The lower limit to the quotas price

The lowest possible quota price will be zero. This price will only be realised if:

1. either new technology makes $CO_2$-reductions almost free, or

2. due to low activity levels (within the EU or outside) there is sufficient of "hot air" to reach the total EU target – and, none of the "hot air suppliers" are able to expel monopoly power, and they are willing to sell quotas at prices next to nothing.

### Other policies, new technology etc.

In general all EU and national policies having an impact on the $CO_2$ emissions will affect quota prices, given an overall reduction target. For example will limitations of car traffic (through taxes or direct regulation (no cars in city centres) and heavy taxation of trucks (on a per kilometre basis) properly reduce emissions, and reduce the demand for and price of quotas.

New technologies may affect the supply and demand for quotas and the quotas price: If new energy saving cars were introduced, if renewable electricity production became cheaper or new energy saving inventions were made, this would increase the low cost potentials for emission reductions and likely reduce the quota price.

### The speed of $CO_2$ reductions

The speed of $CO_2$ reductions may be dependent on the size and wider implications of the investment decision, the profitability of the investments and technological factors. Fuel conversion and for example small-scale windmill investments may be fairly easy to decide on. Decisions to invest in new conventional power plants, large-scale wind or for example hydropower may be harder. High quota prices may ease the investment decisions, and fasten the $CO_2$ reductions.

### Studies of quota prices when backstop technologies matter

The present analysis stress the importance of attention on backstop technologies, the prices at which they become profitable and their emission reduction potentials, in studies of quota prices and costs of $CO_2$ reductions. The present analysis indicates that failure to include backstop technologies may give quota price estimates of limited value.

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